The American Journal of Surgery

VOLUME 97 APRIL 1959 NUMBER FOUR

PRESIDENTIAL ADDRESS

The American Association for the Surgery of Trauma and Its Objectives

To serve as President when an organization comes of age is a fortuitous honor of which I am thoroughly aware. It offers an opportunity to recall the original objectives upon which the organization was founded, to assess its accomplishments to date and to survey its potentialities for the years that lie ahead.

My immediate predecessors have had a similar concern for the future fields of usefulness of this organization. Dr. Kennedy in his Presidential Address very graphically stressed the advisability of this Association's sponsoring and supporting all forms of accident prevention, the importance of obtaining an improved, orderly educational program for the surgery of trauma and better care of the injured under Workmen's Compensation, particularly in the field of rehabilitation.

Dr. Cole very accurately outlined and advocated mechanisms for improvement in the teaching of trauma care, in the treatment of the injured and in the training of the young surgeon in the surgery of trauma.

Dr. Johnston most eloquently and in great detail emphasized the need for extension of the educational opportunities for training and research in trauma, and for the prevention and control of the number and severity of accidents. I find myself rather concerned that in view of these splendid and authoritative pronouncements there has not as yet been evolved a sufficiently adequate blueprint for action whereby these consummations, so devoutly to be wished, may be realized. The notable exception which so splendidly points the way is the Joint Action Program, suggested by Dr. Johnston, between the National Safety Council, the American College of Surgeons and our Association for the prevention of accidents and for better emergency care.

The American Association for the Surgery of Trauma was founded in 1938. This is our eighteenth meeting. The primary objectives of the Association delineated in the certificate of membership are " . . . The cultivation and improvement of the science and art of the surgery of trauma and allied sciences." The early days of this Association were concentrated on justifying its existence as a forum for the meeting of minds of those whose major or sporadic interests were concerned with the surgery of trauma. A rather gradual realization that there was a deservedly important and clear-cut place for a society devoted to betterment in the treatment of trauma came largely through the persistent efforts of a nucleus of early, stalwart protagonists among whom the figure of Kellogg Speed looms large. Dr. Speed, in his address as the first President of the Association, while deploring the tendency toward overspecialization, set forth as the principal aims and ambitions of this organization " . . . the calling back into the fold of the well-trained general surgeon those interested in maintaining high skills and scientific development in the phases of surgery that have to do with trauma," and the rekindling of interest in the surgery of trauma—which in the rapid development of wider and more immediately fascinating fields of surgery had been pushed into the shadows.

In the early years further impetus was given

when ardent investigators of the physiological and metabolic factors associated with trauma were added to our rolls, and younger men taking up the cudgels for better methods in the care of the injured were attracted to our meetings and proved eligible for fellowship. We now have a large application list of those desiring membership, having kept the field open to general surgeons and surgical specialists as well as orthopedic surgeons interested in the surgery of trauma.

This organization has indeed proved a rallying point for those interested in better care of the injured. It has provided a rostrum for the presentation of reports of new techniques and new methods of diagnosis and better treatment of trauma, for evaluation of hitherto acceptable procedures, as well as symposia on trauma peculiar to the atomic age. It has realistically demonstrated, by the ever increasing attendance at our meetings, the value of comprehensive conferences dealing with the surgery of trauma. In the period of our existence, the discovery and advancement in knowledge of the fundamental alterations in body metabolism that occur as a result of injury, and the realization that the trauma of surgical procedures must be regarded in the same category, have greatly stimulated wider interest in the full impact of the effects of injury. No longer can the surgery of trauma be regarded as a detached and intermediate type of surgery fit only to be a stepping stone to more exotic, challenging fields of surgical research; it must be reckoned with as presenting a fundamental background, familiarity with which is essential for success in every type of surgery. The surgery of trauma may be considered therefore as an essential element of the main line rather than a sidetrack in the construction of the new and better right of way for the progress in surgery.

Present trends, as Kellogg Speed so prophetically emphasized, are calling back into the fold of trauma not only the general surgeon but also the surgical specialist.

A number of factors have been implicated in stimulating this resurgent regard for the surgery of trauma and better care of the injured, notably: (1) The continuing interest of many young surgeons who were trained in the surgery of trauma in World War II and were occupied in large part in that type of surgery for four to five years. (2) The need for the continuance of this training and the occupation of younger surgeons for a longer period in the surgery of trauma as a result of the Korean conflict, as well as universal military service for all able-bodied young surgeons in the last ten years in which care of the injured and the end results of war casualties played a large part. (3) Advances and improvement in this field as a result of war experience made applicable to civilian casualties. (4) Disaster experience from fire, storm, flood and hurricane which has emphasized the need for thorough planning throughout the country for care of large numbers of emergency casualties, in which all surgeons regardless of specialty should be prepared to participate. (5) The realization that in atomic age warfare the care of the huge number of simultaneous casualties to be anticipated will involve every surviving individual with medical training, not merely surgeons. (6) The holocaust on our highways from the rising tide of motor vehicle injuries, requiring and demanding in every community surgeons interested and competent in their care, all of which may form an important economic increment in the practice of the young surgeon. (7) Farm casualties and accidents due to the ever increasing use of motorized vehicles and mechanical devices by inadequately trained persons. (8) Finally, the absorbing and fascinating advances in our knowledge of the physiology, pathology and metabolic changes as a result of trauma (particularly as these apply to any operative procedure) have opened wide the doors to a new concept of the fundamental implications of any injury.

In view of the foregoing, the setting up of a program whereby better care of the injured in all categories may be promoted and the coordinating of the sphere of influence of existing organizations toward accomplishing that end would seem the peculiar province and obligation of an organization devoted exclusively to the surgery of trauma. This would not supplant or duplicate any of the efforts already so effectively at work but would be a catalyst, a coordinator in whatever way possible, to set up an over-all program within which all interested physicians and groups will be invited to participate from the planning level on. This may include the exploration of projects not as yet undertaken by any group or the investigation of programs already in existence, with the intent, by appropriate conference and cooperation, to make that work or plan more effective.

Nothing could better illustrate the potentiality of this type of procedure than the activation, through the vision of Dr. Charles Johnston, of joint action by The American Association for the Surgery of Trauma, the National Safety Council and the American College of Surgeons to set up a nationwide cooperative plan for the prevention of accidents and for better emergency care. The organizations providing the functional elements for accomplishment are the National Safety Council and the American College of Surgeons, the American Association for the Surgery of Trauma acting as a counseling group. The local and district councils and conferences of the National Safety Council and the local and regional committees on trauma of the American College of Surgeons are the specific elements between which liaison can be effective in accomplishing the desired objectives.

More widespread interest in education in the care of the injured and in the surgery of trauma has for many years—really since its inception—been one of the chief concerns of the Committee on Trauma of the American College of Surgeons. A subcommittee on education, of which Dr. Harrison McLaughlin is the most recent chairman, has from time to time made efforts to enlarge the scope of training of surgeons in trauma. His masterful oration on "Education in Trauma," delivered over a year ago at the Clinical Congress, epitomizes the requirements for indicated broader bases of approach and measures to obtain the long desired end results. In recent years many magnificent and specific suggestions for making the teaching of the surgery of trauma more effective have emanated from our membership. In this atomic age it is imperative for every technician in every surgical field to have a modicum of basic training and knowledge in surgery of the injured. Would it not be an appropriate function of this organization to take some action by which a conference group would be set up to consider the requirements of training in the surgery of trauma in order that a plan of action or procedure could be agreed upon or outlined? To that conference should be invited representatives of the medical schools and those organizations interested in the teaching of trauma care such as the Association of American Medical Colleges, The American College of Surgeons, the American Surgical Association and the Council on Medical Education and Hospitals of the American Medical Association. Stress would be laid upon what to teach and where; first, at what levels of training, undergraduate or graduate; second, whether or not any new training centers are needed and minimum standards for them; and third, whether training in the surgery of trauma should be part of the training of every resident in surgery or a surgical specialty.

It is timely that the place of the surgery of trauma in the training of a surgeon should be evaluated and recognized on all sides; that lessons so widely learned as a result of the need for many surgeons for the care of war casualties are not forgotten and abilities universally acquired do not "lie fallow between conflicts" as has been true so consistently in the past.

A joint conference with the Committee on Trauma of the American College of Surgeons might develop other areas in which a coordinating group could be helpful in furthering projects or objectives under consideration by this magnificent working unit.

The American Medical Association, through its Council on Industrial Health and its committees on rehabilitation, on medical rating of physical impairment, and on medical aspects of automobile injuries and deaths, has developed programs, knowledge of whose details would be useful whenever a nationwide coordinated effort in these fields is planned. Their bearing upon cooperative effort for better surgery of the injured or end results in trauma should certainly be evaluated.

I have merely outlined a few suggestions for broader activities and influence for this Association. These would seem to be appropriate and perhaps imperative if there is vision and conviction as to the actual place surgery of trauma should hold in the light of present day trends. The method of approach to this problem, however, should be orderly. A mere reference to certain potentialities is not sufficient ground upon which to base definitive action.

It would seem logical that an over-all planning committee or commission should be appointed to study activities in the field of trauma as they exist today, and to set up a plan whereby this Association can further to the utmost better surgery of trauma and its more efficient application to the care of the injured. The purposes of such a committee would not be to supplant but to collaborate with the work of others to make their efforts more effective, to

originate new projects only when indicated (not necessarily exclusively for our organization but also for the development of plans for the most efficient joint action), and to use the programs of our meetings as it may seem fit for the furtherance of these ideals. Perhaps some change in, or expansion of, our meetings might be indicated.

Thus it would seem appropriate to appoint another committee whose duties might include: (1) review of advances in research in the surgery of trauma to insure that adequate reports concerning expanding horizons in trauma might promptly be included in our programs; (2) suggestions to the membership for papers on specific topics of lively interest when the request for contributions to the program is broadcast; (3) study of our present programs to determine if any change is desirable; (4) the advisability of submitting end result studies of joint action programs at our executive sessions.

In presenting this brief survey of the present day position of the surgery of trauma I have attempted to indicate that an association devoted to the surgery of trauma and better care of the injured has responsibilities and legitimate objectives. Certainly mature and careful consideration and study of appropriate means to attain those objectives should precede any action toward accomplishment. In view of the many splendid efforts already in existence in this field, coordination and cooperation with present day plans of other organizations should have high priority in any action to be undertaken. Rearranging or altering the format of the programs of our meetings to maintain intimate contact with progress in the field of trauma should strengthen their value and their contribution to the better and wider understanding of the important position surgery of trauma now occupies. As an organization we have just come of age. We should be "rejoicing as a strong man to run a race." Certainly the enhancement of this organization's influence in improving the application of the science and art of the surgery of trauma to the better care of the injured should be an objective in which every member can share.

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One Hundred Cases of Low Back Pain

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ONE hundred cases of low back pain were reviewed. No attempt at selection was made. These cases simply represent 100 patients who presented themselves complaining of low back pain.

When indicated, complete blood count, sedimentation rate, urinalysis, serology and prostatic smear were performed. Examination consisted of a general physical examination, and orthopedic and neurological examinations relative to the back and lower extremities. Included were tests for posture deformity, muscle spasm, peripheral pulses, range of motion of spine, clonus, function of the extensor proprius hallucis and peroneal muscles, measurement of the extremities for atrophy and leg length, acute flexion of the thigh, straight leg raising, tests for the LaSègue sign, the Babinski reflex, and the Trendelenburg and kneeling bench tests.

Discharge from treatment was based upon: (1) the patient's statement that he was symptom free; (2) normal range of motion in the spine without pain; (3) the absence of muscle spasm; (4) the ability to drop on heels without pain; and (5) the ability to squat and resume erect posture without difficulty.

When symptoms were minimal, outpatient treatment and the continuance of work were encouraged. If symptoms were disabling but not aggravated by ordinary activity, the patient was advised not to work and treatment was carried out on an outpatient basis. When symptoms were severely disabling or minimal activity would cause further aggravation of symptoms, the patients were hospitalized. All of these patients were personally examined and treated.

Outpatient treatment consisted of infra-red rays or diathermy and massage, adhesive strapping, medication for pain when indicated, instructions in use of bedboards and, in some instances, the use of orthopedic corsets. Additional forms of therapy such as local injections, use of muscle relaxants and local counterirritants were considered to be of no value.

Hospital treatment consisted of complete bed rest, with or without jackknife positioning, and continuous hot packs for forty-eight hours. If this did not relieve spasm and pain, bilateral Russell's traction was applied followed by physical therapy. Fractures of the spine and herniated discs were treated by appropriate support and/or surgery.

These cases have been analyzed in an attempt to evaluate the cost of treatment necessary to restore these patients to employment or to evaluate and compensate for permanent disability. Evaluation is also made to determine what the industrial surgeon can expect during the course of treatment of 100 unselected cases of low back injury. Correlation is attempted between objective physical findings and x-ray findings and the degree and length of disability of these cases.

OUTPATIENT CASES

Eighty-one patients were treated on an outpatient basis. In thirty-nine the onset was characterized by sudden onset of sharp pain in the low back while lifting or straining, pushing or pulling. (Table 1.) Twelve of these patients had normal spines on x-ray examination. Of the twelve, physical examination was negative for abnormalities in seven while five had evidence of varying degree of muscle

TABLE I
SUDDEN PAIN WITH LIFT, STRAIN, PUSH OR PULL
(39 CASES)

X-Ray Findings	Previous History (No. of cases)	Length of Treatment (days)	Temporary or Permanent Disability (days)
Negative (12 cases)	2 (16.7%)	10.3	0
Positive (27 cases)	6 (22.2%)	19.6	24 days (1 case—10% permanent disability)

spasm, limitation of motion in forward flexion and flattening of the lumbar curve. Length of treatment varied from one to forty-two days (average 10.3 days) with no temporary or permanent disability. The total cost of treatment in this group was $676.64.

The remaining twenty-seven patients had roentgenologic evidence of sufficient abnormality so that they would have been rejected on pre-employment x-ray examination. Of these, seventeen had objective physical findings of muscle spasm, limitation of flexion, limitation of straight leg raising, secondary scoliosis, pelvic tilt or flattening of the lumbar curve. In the remaining ten, there were no findings on physical examination. The length of treatment varied from one week to three months. There was temporary disability of two days in one case and one year in another case; the latter ultimately proved to be a herniated intervertebral disc for which laminectomy was performed by the patient's own surgeon with 10 per cent permanent disability of the body as a whole. This patient continues to have recurrent bouts of disability after the laminectomy. The average length of disability in this group was twenty-four days. The length of treatment averaged 19.6 days in this group with the exceptions of one patient who was treated for a period of three to four years and one who was treated for a period of one year. There was a history of previous disability due to back symptoms in six of the patients with positive roentgenograms of the back and in two of those with normal x-ray films of the back. Orthopedic consultation was obtained in four of these cases and in one laminectomy for intervertebral disc was performed.

Final diagnosis was paravertebral muscle strain in twenty-three cases, postural strain with unequal leg length in two, sacralization of L_5 with pseudoarthrosis in one, spondylolisthesis in one, and herniated intervertebral disc in one. The total cost of treatment in this group was $12,153.64.

Twelve patients sustained injury to the back in a fall. (Table II.) The mechanism of injury was a direct blow to the spine with the person in a sitting position or from a fall flat on the back. One of these patients had a previous history of compression fracture of the spine. X-ray films of the spine were negative for abnormalities in seven cases. Physical findings were positive in all patients, varying from an area of tenderness and contusion to severe muscle spasm. There was no disability in five of these seven cases and treatment averaged three days. In the remaining two cases loss of time was two weeks, and treatment was thirteen days for one and six months for another. The average temporary disability lasted four days and the average length of treatment was thirty days. Orthopedic consultation was obtained for one patient. Final diagnosis was contusion in five cases and paravertebral muscle strain in two.

Five of these patients had x-ray films showing varying degrees of arthritis, narrowing of the joint spaces and old, healed compression fracture of the vertebral body. These patients had clinical evidence of muscle spasm and contusion and abrasions to the low back area. The average disability was thirteen days, with no permanent disability and 15.2 days was the average length of treatment. Additional diagnoses of obesity, hypertension, calcified fibroid of the uterus and congestive heart failure were made in two cases. The total cost of treatment in this group was $4,620.00.

Twelve patients received twisting and

TABLE II
INJURY FROM A FALL (12 CASES)

X-Ray Findings	Previous History (No. of cases)	Length of Treatment (days)	Temporary or Permanent Disability (days)
Negative (7 cases)	1 (14%)	30	4
Positive (5 cases)	1 (20%)	15.2	13

TABLE III
TWISTING OR WRENCHING INJURIES
(12 CASES)

X-Ray Findings	Previous History (No. of cases)	Length of Treatment (days)	Temporary or Permanent Disability (days)
Negative (5 cases) . .	0	14	23 days (1 case)
Positive (7 cases) . .	1 (14%)	22	70 days (1 case)

wrenching injuries while trying to prevent falling. (Table III.) Five of these patients showed normal findings on x-ray examination. There was paravertebral muscle spasm, limitation of motion and loss of normal lumbar curve in four of these; one of these patients also showed unequal leg length. The fifth patient showed no objective findings. One patient lost twenty-three days due to temporary disability, the remainder, none. The average length of treatment was fourteen days and the final diagnosis was paravertebral muscle strain or lumbar strain. Of the seven patients with positive x-ray findings in this group, one had a previous history of recurrent "lumbago." Only one of these patients had positive physical findings and this consisted of a hysterical diminution of sensation on the entire right side of the body. This patient required ten weeks of treatment, sedation and orthopedic consultation, and there were ten weeks of temporary disability. The remaining patients required an average of twenty-two days of treatment and there was no temporary or permanent disability. The total cost of treatment in this group was $2,640.70.

Three patients sustained direct blows to the back. All three of these had positive x-ray findings of pre-existing lesions. In none of these was there a previous history of injury. One of these patients, who was an alcoholic, ultimately admitted that he had lied and that he had not sustained injury at work. Physical examination was negative for abnormalities in the remaining two. The average length of treatment was forty days and there was no permanent disability. Diagnosis was contusion to the low back area. The total cost of treatment in this group was $155.35.

Eleven patients gave no history of definite mechanism of injury. (Table IV.) The onset of back pain was insidious or had been recurrent many times over a period of months or years. Only four of these patients claimed no previous history of back disability. Of these four, three had evidence of arthritis on x-ray examination and one had a normal back on roentgenograms. Only one of these patients had muscle spasm and in the other three there were no positive physical findings. Treatment varied from one week to three months and temporary disability was three months in one case; none of these patients was accepted as an industrial liability. Orthopedic consultation was obtained in two cases and the Industrial Commission of Wisconsin denied a claim for industrial disability in one.

In the remaining seven patients there were varying degrees of arthritis, narrowing of joint space and sclerosis of the facets. In three of these there were no positive physical findings and treatment lasted one week on the average with no disability. The remaining four had varying degrees of muscle spasm and limitation of motion, voluntary rigidity and grossly exaggerated complaints. None of these patients was accepted as an industrial liability and no disability was allowed. These patients claimed temporary disability varying from fifteen to sixteen days to a maximum of fifteen months. The total cost of treatment in this group was $31,343.14.

The last group of these outpatients consisted of four patients with bizarre claims of back injury varying from injury while bending over normally while at work to injury while sitting in a crane which struck a hole and jarred the patient's back. The third claimed sudden pain while climbing a telephone pole and the fourth claimed sudden pain while working in a stooping position. All four denied previous history

TABLE IV
NO MECHANISM OF INJURY (11 CASES)

X-Ray Findings	Previous History (No. of cases)	Length of Treatment (days)	Temporary or Permanent Disability
Negative (1 case). . . .	4	7	0
Positive (10 cases) . .	7 (70%)	93	0

TABLE V
EIGHTY-ONE OUTPATIENT CASES

X-Ray Findings	Length of Treatment (days)	Temporary or Permanent Disability (days)
Negative (25 cases)...	15.3	27
Positive (56 cases)	36.5	95 (1 case—10% permanent disability)

of back pain. X-ray films revealed degenerative changes in all four and physical examination revealed minimal muscle spasm and minimal limitation of flexion of the spine in two of the four. There was no temporary or permanent disability and treatment averaged three and a half weeks. The final diagnosis in these was mild fascitis. The total cost of treatment in this group was $288.30.

In this series of eighty-one patients treated on an outpatient basis (Table v), the length of treatment was longer and temporary or permanent disability greater in the fifty-six patients who had positive x-ray findings than in the twenty-five patients who had normal x-ray studies of the back. Only one of these eighty-one patients was awarded permanent partial disability.

HOSPITAL CASES

Nineteen patients were hospitalized because of acute symptoms which were obviously thought disabling when they were first examined, or following treatment on an outpatient basis without objective or symptomatic improvement. (Table VI.)

Six of these patients were injured in falls from varying heights; nine were injured while lifting, pushing or twisting against resistance. Two were injured by direct blow to the low back area. Sudden pain developed in one when he twisted to get to his feet from his seat, and sudden pain developed in another while he was walking through the shop.

Five of these patients had a previous history of back injury or disability. Only four of these patients had normal spines on x-ray examination. Physical findings included paravertebral spasm, Grade 3 to 4, in all cases. Local evidence consisted of contusion or abrasion, limitation of motion in all planes, limited straight leg raising, scoliosis, loss of normal lumbar curve, reflex changes and complaints of severe pain. The length of hospitalization varied from two to three days in one case of acute back strain to nine weeks. Traction was applied for an average of six and a half days. Follow-up outpatient treatment was necessary for a period of three to four weeks in most cases. The average temporary disability was eight to ten weeks. Permanent disability on one patient is unknown because he signed his release from the hospital to go to California to sue the company. There was no permanent disability in nine of these cases. The remainder resulted in permanent disability from compression fractures with associated fractures of the transverse processes; fracture of several transverse processes occurred in two cases, one of which was determined at 5 per cent permanent partial disability of the body as a whole, one year after injury, and for one of which a permanent disability is still unknown as the patient is in the process of suing the employer.

Two patients had laminectomy performed for herniated intervertebral disc by orthopedic surgeons, with an average of five months temporary disability and 5 per cent permanent partial disability of the body as a whole. Five patients were seen in consultation by an orthopedist to confirm the clinical diagnoses of herniated intervertebral disc. Of these, four have had recurrent acute episodes of periods varying from five months to three years; laminectomy has been advised in four but has not been carried out. Disability with each of these recurrences has averaged five weeks, and for two of these patients industrial liability has not been accepted.

One patient left the hospital voluntarily to avoid becoming a reportable injury by remain-

TABLE VI
HOSPITALIZED (19 CASES)

X-Ray Findings	Previous History (No. of cases)	Length of Treatment (days)	Temporary or Permanent Disability (days)
Negative (4 cases)	0	19.8	20 (3 cases, 1 unknown)
Positive (15 cases)	5 (33%)	36	56–70 (5 permanent disabilities)

ing in the hospital over seventy-two hours. He has been treated on repeated occasions in the outpatient department for a period of fifteen months following this cooperation with the foreman without relief from symptoms. The final diagnosis was acute back strain with temporary total disability in ten cases, herniated intervertebral disc with laminectomy and permanent disability in two cases, fractures of the vertebrae or transverse processes with permanent disability in two cases, and presumptive or definite clinical diagnosis of herniated intervertebral disc without laminectomy in five patients, four of whom have had recurrent bouts of disability since the original diagnosis was established. The total cost of treatment in this group was $69,614.05.

The total cost of these 100 cases was $121,491.82 or an average of $1,214.91 per case.

Here again, for the fifteen patients with positive x-ray findings the length of treatment required was twice as long and the length of temporary disability over three times as long as in those patients with negative x-ray findings. Permanent disability resulted only in patients with positive x-ray findings.

Of the 100 cases reviewed, there were twenty-nine patients who had normal roentgenograms of the back. Three of these (10.3 per cent) had histories of previous back disability. Seventy-one patients had demonstrable pathologic conditions on x-ray examination, and twenty of these (28.1 per cent) had histories of previous back disability.

In the past four years pre-employment x-ray films of the back have been taken on a total of 595 applicants for employment. One hundred eighty-five, or 31 per cent, of these applicants have been rejected because of x-ray findings indicative of probable future disability relative to the low back. This is lower than the 45 per cent rate reported by Colcher and Hursch [1]. Reiner [2] reports a 23.5 per cent rejection rate and Runge [3] a 10 per cent rejection rate. On the basis of this study one can assume the average cost of treatment of these 100 patients would then be saved in the one hundred eighty-five applicants who were rejected in pre-employment examination. This represents a saving of $223,758.35.

It is also possible that some of these 100 persons would have been rejected for employment had they applied during the period that these pre-employment x-ray films of the back were taken.

Rejection on pre-employment roentgenograms of the back is based upon the following findings: (1) moderate or advanced arthritis, (2) evidence of old compression fracture, (3) rotory scoliosis, (4) defects in the pars intra articularis or neural arch, (5) evidence of degenerative bone disease such as osteoporosis, (6) spondylolisthesis, (7) transitional vertebrae when a definite psudoarthrosis is present, (8) definite evidence of residual epiphysitis with deformity, (9) disc changes, (10) sclerosing osteoitis or zygoapophysitis of the articular facets, (11) single Schmorl's nodes with loss of normal lumbar curve, (12) multiple Schmorl's nodes, (13) evidence of narrowing of lumbosacral joint, (14) tumors and (15) reactive changes about sacroiliac joints in young applicants.

Not only do these x-ray examinations prevent potential claims, but they constitute a permanent record by which subsequent disability can be accurately evaluated by comparative study.

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Some Observations Regarding 905 Patients Operated upon for Protruded Lumbar Intervertebral Disc

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Low back and sciatic pain remains a complicated problem and the results of surgery upon those who suffer leave much to be desired. A review of the case histories of our patients operated upon for protruded lumbar disc was undertaken in the hope that the facts disclosed would increase our understanding of the problem. During the last twenty years we have explored 905 patients for protruded lumbar intervertebral disc.* All of the operations performed on these patients were carried out in private hospitals. No patient at the medical school hospitals was included in this series.

Eighty-six of our 905 patients had had surgery on the low back before we saw them because of symptoms suggesting protruded intervertebral disc. I do not intend to criticize in any way the previous surgery, for in this review it was found that forty-six (5 per cent) of the 905 patients were explored by us two or more times for persistence of symptoms of protruded intervertebral disc. In our hands, forty-three of the forty-six patients had had two explorations each, and three patients had had three explorations each, to make a total of 954 operations which we performed upon the 905 patients.

The surgical technique was standard. Spinal anesthesia was usually employed, supplemented with Pentothal® sodium (thiopental sodium) if the patient was apprehensive or restless. The patient was operated upon in the prone position with the table flexed in order to open the interlaminal spaces. Removal of bone from the laminas to expose the protrusion was kept to a minimum; except in the early cases, a lamina was rarely interrupted completely. After removal of the protruded portion of the disc, the interbody space was curetted to remove all of the nucleus pulposus. When a spinal fusion was indicated, I worked with an orthopedist. A Hibbs type of fusion, bone being taken from the crest of the ilium, was the usual method employed. No interbody fusions were performed on patients in this series.

* Eight hundred seventeen patients were operated upon by the author and eighty-eight were operated upon by his associates in private practice.

FINDINGS AT OPERATION

In evaluating the operative findings, only those patients whose first operation for protruded disc was performed by us have been included in this study. The patients operated upon elsewhere, prior to our primary operation, were not included because of the alterations in structure that might have resulted from the original operation. Eight hundred nineteen of the 905 patients had their primary operation performed by us, and Figure 1 reveals our operative findings in this group. Forty-five patients (5.5 per cent) of the 819 were found to have nerve root lesions other than protruded disc, which we thought were capable of producing the symptoms of which the patients complained. Included in these other nerve root lesions are arachnoiditis, radiculitis, scar tissue, adhesions, and osteoarthritic spurs impinging upon the nerve root.

Single protruded intervertebral discs were found in 610 patients. In another fourteen patients protrusions at two levels were present.

In 150 patients (18.3 per cent) no gross nerve root lesions were uncovered which we considered responsible for the patient's symptoms. Prior to operation on most of these patients we thought there was a possibility rather than a

probability that a protruded disc was present. At the time of surgery, an orthopedist and a neurosurgeon usually operated together with the understanding that as long as a spinal fusion was indicated, the neurosurgeon should look for a protruded disc. The fact that a great many in this group of 150 patients had spinal fusions as well as explorations for protruded disc indicates that we thought some structural defect was responsible for the low back and sciatic pain simulating disc symptoms.

We have used such diagnoses as hypertrophied ligamentum flavum, constriction of the nerve root, small intervertebral foramen and enlargement of the nerve root very infrequently, and I have considered the use of these terms an excuse for not finding a protruded lumbar disc. We also have been very hesitant to call a high annulus a protruded intervertebral disc or to blame such a condition for the patient's symptoms. In the 819 primary operations that we performed, single protruded discs were found in 610 patients. (Table 1.) Five hundred fifty-eight of the 610 protrusions were herniations of the nucleus pulposus. Thirty-six protrusions of the annulus were thought to be the cause of symptoms, and in sixteen instances both annulus and nucleus pulposus were herniated. When two protrusions were found, twenty-four were herniations of the nucleus pulposus and four were protrusions of the annulus.

As is well known, most of the protrusions occur at one of the last two disc spaces. In this series 96 per cent of the total number of protruded lumbar discs were found in the last two disc spaces. (Fig. 2.)

AGE, SEX AND HISTORY OF PREVIOUS INJURY

The charts of 665 patients with surgically proved protruded lumbar discs were examined for age, sex, and history of back injury. (Fig. 3.) The age at onset of definite symptoms of protruded disc was used in the tabulation and it was found that most of the patients were between the ages of thirty and fifty. The youngest patient from whom I removed a protruded disc was eleven years and the oldest eighty-one years. The latter patient had two operations for protruded disc, one recently and one several years previously.

A fifth of the patients were females. Seventy per cent of the patients with proved protruded discs gave histories of specific back injury.

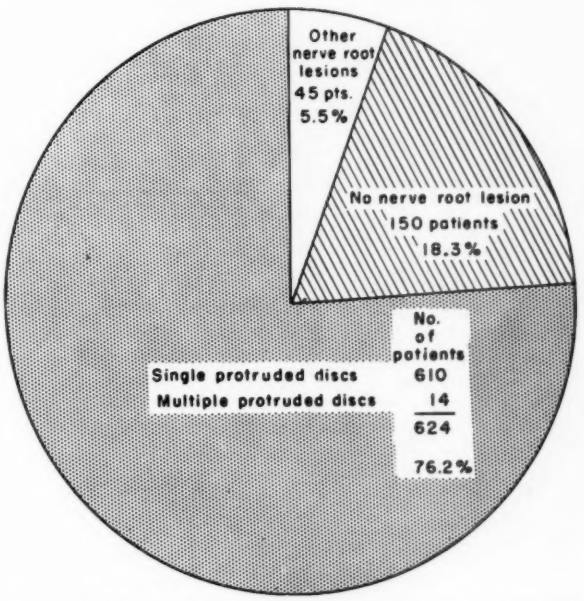

FIG. 1. Findings at primary operations on 819 patients.

SYMPTOMS, SIGNS, LABORATORY AND X-RAY FINDINGS

The symptoms, signs, laboratory and x-ray findings in patients with protruded intervertebral discs have been evaluated and these findings compared with those in patients whose surgery failed to reveal protruded discs. In the appraisal of symptoms and signs only those patients whose primary operation was performed by one of my associates or me have been used in this study. I was of the opinion that if a patient had been operated upon elsewhere, the symptoms and signs produced by the protruded intervertebral disc might have been altered by the surgery previously performed. Figure 4 shows that back pain was present in 83 per cent

TABLE 1
PROTRUDED LUMBAR DISCS FOUND IN 819 PATIENTS (PRIMARY OPERATIONS)

Condition	No. of Patients
Single protruded discs (610 patients)	
Protruded nucleus pulposus	558
Protruded annulus	36
Protruded annulus and nucleus pulposus	16
Two protruded discs found at different levels (14 patients)	
Protruded nucleus pulposus	24
Protruded annulus	4
Total	638

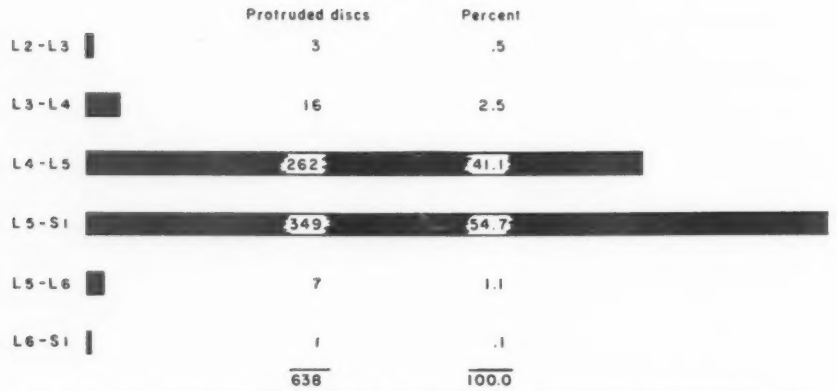

FIG. 2. Distribution of 638 protruded lumbar discs found in primary operations.

of patients with protruded disc, whereas in the groups of patients who had other nerve root lesions or no demonstrable nerve root lesion, 11 or 12 per cent more patients had back pain. The radiating-type of leg pain occurred with the same frequency in all three groups. Bilateral leg pain was a complaint more often in the group with no demonstrable nerve root lesion. The frequency of limitation of back motion also did not differ greatly in the three groups of patients. (Fig. 5.) Sensory loss in the leg was somewhat higher in those who had nerve root lesions other than protruded disc. A positive Lasègue's sign occurred in patients in the three groups with about the same frequency, and pain on straight leg raising on the unaffected side was present in about the same percentage of patients in the three groups.

I was formerly of the opinion that if one would place his thumb on the patient's back over the suspected site of a protruded intervertebral disc and apply pressure, radiation of pain down the leg was almost pathognomonic of a protruded lumbar disc. Actually this opinion was found to be erroneous. (Fig. 6.) As a matter of fact, more patients with other nerve root lesions had this finding than did patients with protruded discs. However, this finding was present more often in patients with protruded discs than in those in whom no nerve root lesion was found.

Loss of bladder control was present in fifteen (2 per cent) of the 624 patients with protruded discs. One patient with some other type of nerve root lesion had loss of bladder control, while no patient without a demonstrable nerve root lesion had urinary incontinence.

Four patients with protruded discs had loss of bowel control, whereas none in the other two groups had this complaint.

Considering 40 mg. per cent as the upper limit of normal for total protein in the spinal fluid, 63 per cent of the patients with protruded discs had total protein above that level. Sixty-eight per cent of the patients with other nerve root lesions and 41 per cent of the patients in whom no gross nerve root lesion was found had elevated total protein.

The 819 patients were studied for reflex changes. (Fig. 7.) The Achilles reflex may be decreased when the protruded disc is located at any of the last three disc spaces. There were sixteen protruded intervertebral discs found between the third and fourth lumbar vertebrae, and six (38 per cent) patients with protruded discs at that level displayed a decrease in the Achilles reflex on the affected side. Of the patients with protruded discs at the L4–L5 level, decrease in the Achilles reflex was found in 45 per cent. The Achilles reflex was reduced in 71 per cent of the patients with protruded discs

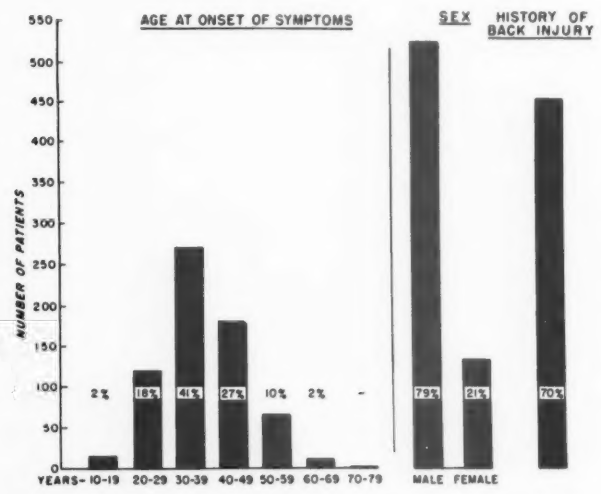

FIG. 3. Six hundred sixty-five patients with surgically proved lumbar protruded disc.

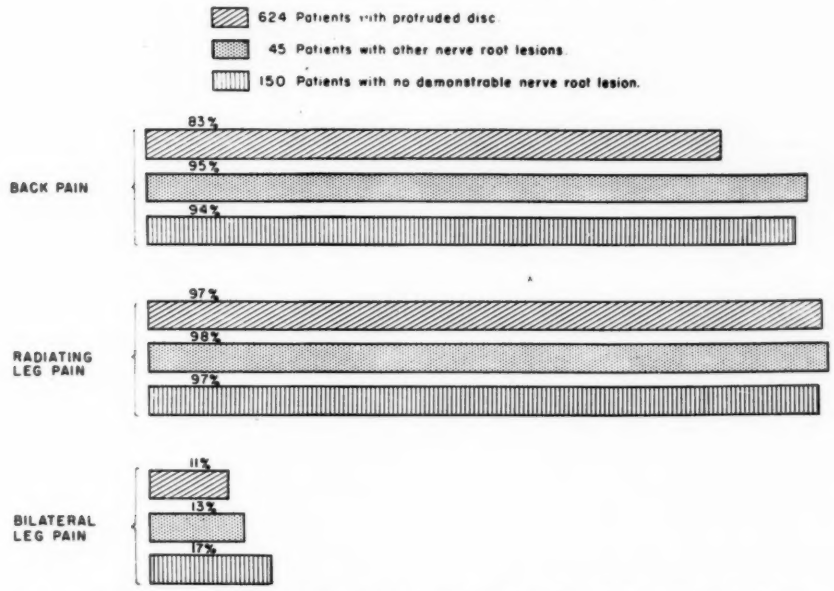

FIG. 4. Symptoms and findings in 819 patients explored for protruded intervertebral disc (primary operations).

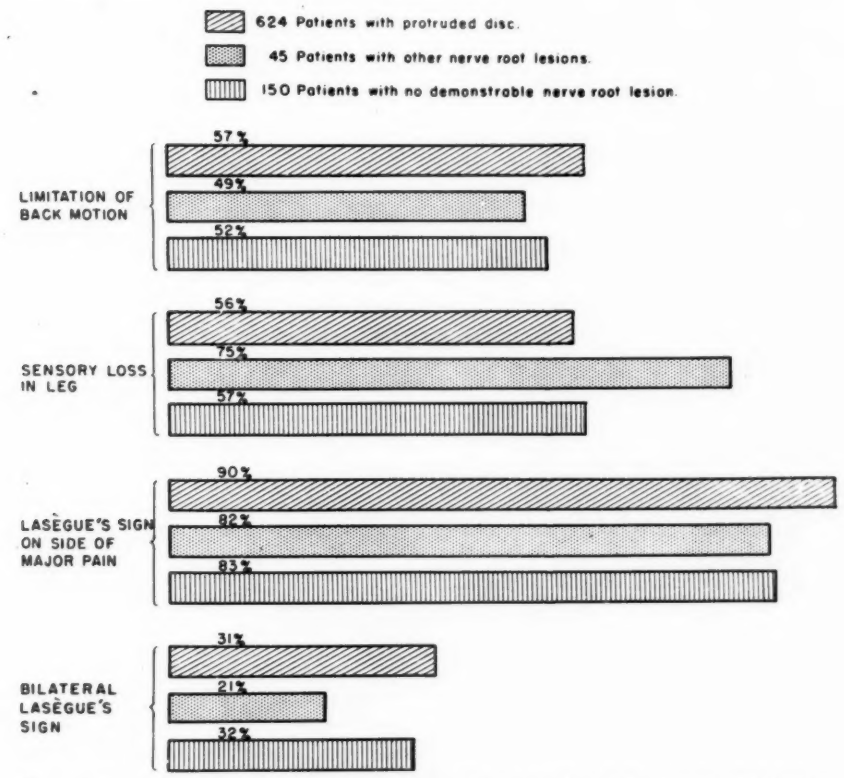

FIG. 5. Symptoms and findings in 819 patients explored for protruded intervertebral disc (primary operations).

between L5 and S1. In the patients with other nerve root lesions, 47 per cent had a reduced Achilles reflex, while in the 150 patients who displayed no demonstrable lesion, 37 per cent had a decrease in the Achilles reflex.

If the patellar reflex is reduced, the protrusion is probably at the L3–L4 space. (Fig. 8.) In the patients who were proved to have protruded discs between L3 and L4, 44 per cent had a reduced patellar reflex on the affected side.

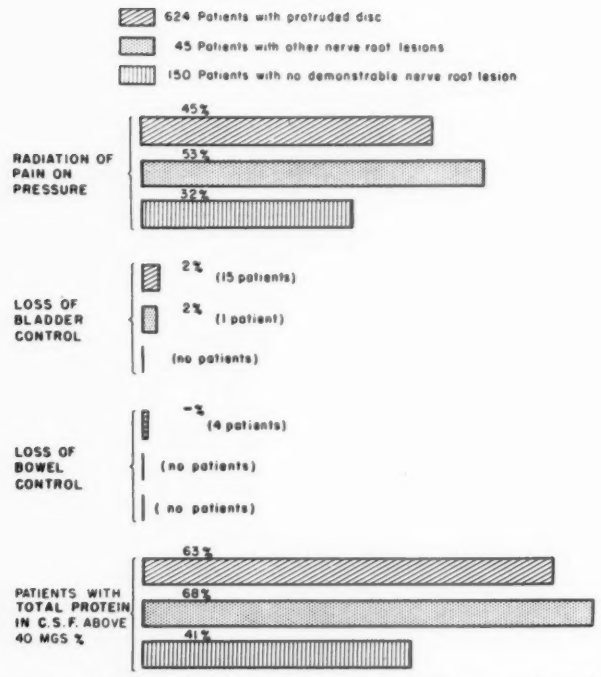

FIG. 6. Symptoms and findings in 819 patients explored for protruded intervertebral disc (primary operations).

Eleven per cent of patients with protrusions between L4 and L5, and 9 per cent of those with protrusions between L5 and S1 displayed a unilateral reduced patellar reflex. Less frequently the patellar reflex was reduced in patients with other nerve root lesions and in those who had no demonstrable nerve root lesion.

The significance of narrowing of disc spaces as visualized by roentgenograms is shown on Figure 9. A narrowed disc space between L5 and S1 was present in 49 per cent of the patients who were found to have protruded discs at that level. On the other hand, 35 per cent of the patients with protruded discs between L4 and L5, and 35 per cent of those who had no demonstrable nerve root lesion proved to have narrow L5–S1 disc spaces on the roentgenograms. Therefore, one cannot rely on roentgenographic evidence of a narrow disc space between L5 and S1 as being indicative of a protruded disc at that level. A narrow disc space between L4 and L5 was present in 14 per cent of the patients with protruded discs between L4 and L5. In our series of patients with protruded discs between L5 and S1, the L4–L5 disc space was narrow in 3 per cent. In four per cent of the patients with no demonstrable nerve root lesion, the L4–L5 disc space was narrow.

ACCURACY OF CLINICAL DIAGNOSIS AND PANTOPAQUE® STUDIES

It has been our practice to write the clinical diagnosis on the patient's chart before taking a myelogram. These clinical diagnoses were evaluated in the 905 patients. (Fig. 10.) Our clinical judgment in diagnosing protruded intervertebral discs was found to be 82 per cent correct.

The results of the Pantopaque (ethyl iodophenylundecylate) tests in 765 patients operated upon for protruded disc were studied. If the Pantopaque test failed to reveal a defect but we operated on the basis of clinical diagnosis and found a protruded disc, we counted this as a "miss" for myelography. If the Pantopaque test showed a defect which was thought to be a protruded disc and at operation no protruded disc was found, this also was counted as a miss for the test. Strangely enough, the accuracy of

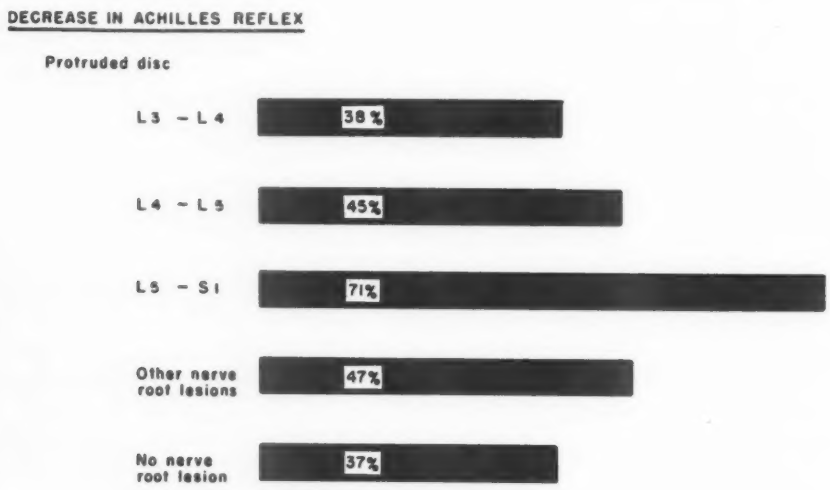

FIG. 7. Reflex changes.

the Pantopaque study was about the same as the accuracy of our clinical judgement, in other words 82 per cent (Fig. 10). One might then ask why a Pantopaque study should be made. We do a study with the contrast medium in the hope that: (1) it will more accurately differentiate between a protrusion at the L4–L5 and L5–S1 disc spaces, (2) it will rule out spinal cord tumor, (3) it will indicate whether the patient has multiple discs, and (4) it will help correct some of our errors in clinical judgment. Figure 11 shows the correlation of clinical diagnosis and Pantopaque studies. In 72 per cent of the 765 patients upon whom a Pantopaque study was performed, both the clinical opinion and the myelogram were correct. In 7 per cent both were incorrect. The clinical diagnosis was correct and the Pantopaque study incorrect in 11 per cent and the reverse was true in 10 per cent of the patients.

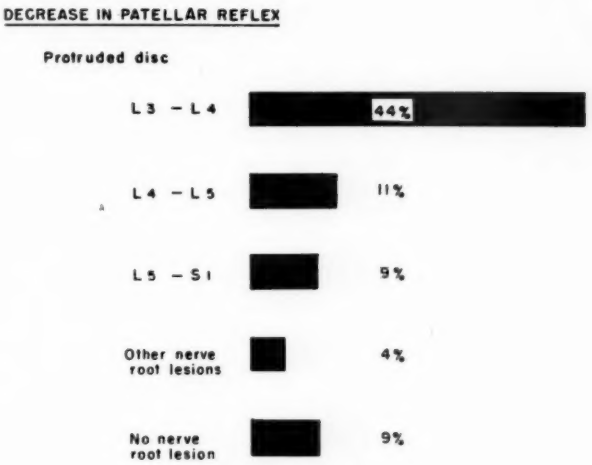

FIG. 8. Reflex changes.

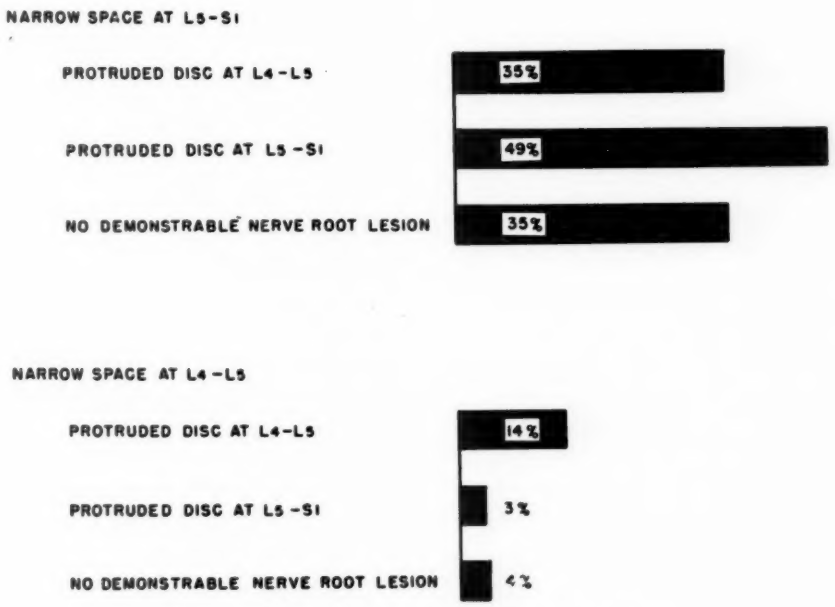

FIG. 9. Significance of narrow disc space (x-ray).

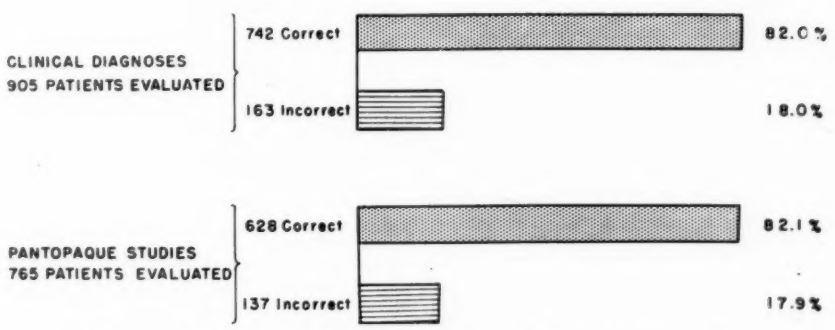

FIG. 10. Accuracy of clinical diagnoses and Pantopaque studies.

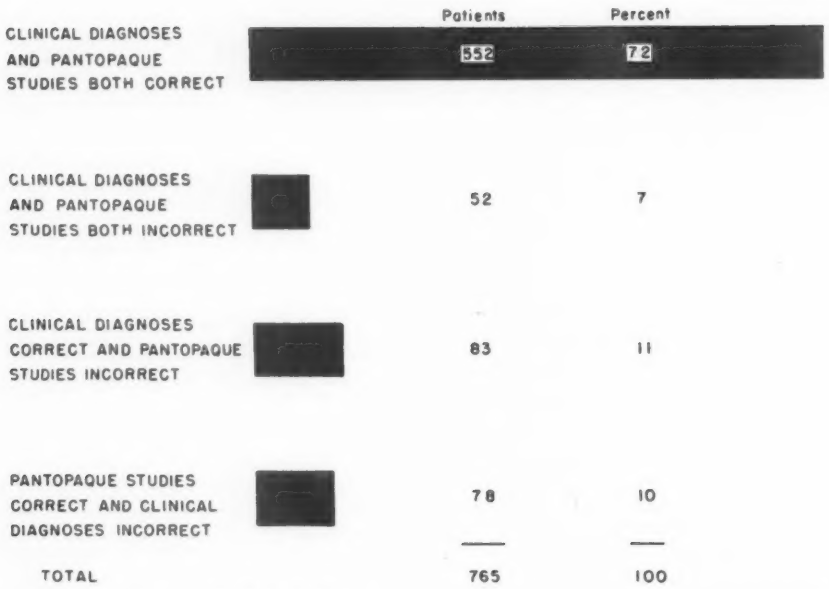

FIG. 11. Comparison of clinical diagnoses and Pantopaque studies in 765 patients.

RESULTS

No patient whose postoperative period was less than one year was included in the study of results. Sixty-one patients were operated upon during the past year; this reduced the number which we attempted to evaluate to 844. We were unable to trace seventy-seven (9 per cent) and, therefore, our results are reported on 767 of the 905 patients in this series. (Fig. 12.) We have segregated our patients so far as results are concerned into excellent, good, fair and poor. Forty-three per cent of the patients were classified under excellent; 37 per cent had good results; 14 per cent fair results; and 6 per cent poor results.

Repeat explorations by us were carried out upon forty-six of the 905 patients. Forty-three of the forty-six had one repeat operation, and three of the forty-six had two more explorations each for protruded intervertebral disc. Twelve patients were found to have a recurrence of the protruded intervertebral disc at the site which had been explored previously. Protruded discs were found to have developed in 15 at a level other than the one from which the protruded disc had been removed at the first operation.

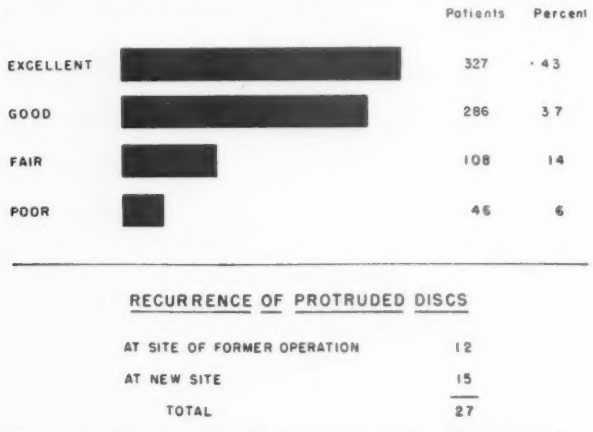

FIG. 12. Results in 767 patients explored for lumbar protruded disc (minimum of one-year follow-up).

It is well known that a "cure" on a "compensation case" is more difficult to effect than a cure upon a patient who is paying his own bills. I have attempted in Figure 13 to bring out the relationship of results to financial responsibility. The results in this analysis are based on those patients who were proved to have protruded intervertebral discs and who had been operated upon more than one year previously. In this series there were forty-two patients who could not be followed up. The 540 patients whom we were able to study were divided into three categories: (1) private patients with no insurance coverage, (2) patients who had insurance that did not carry a disability rating, and (3) patients with insurance who, when their cases became "stationary," were rated for disability and financially rewarded for their disability. Those in the second category carried insurance in a wide variety of agencies such as Blue Cross, Oregon Physicians' Service, Oregon Teamster Security Funds, and many other private insurance companies. In the third category were patients covered by five different agencies which

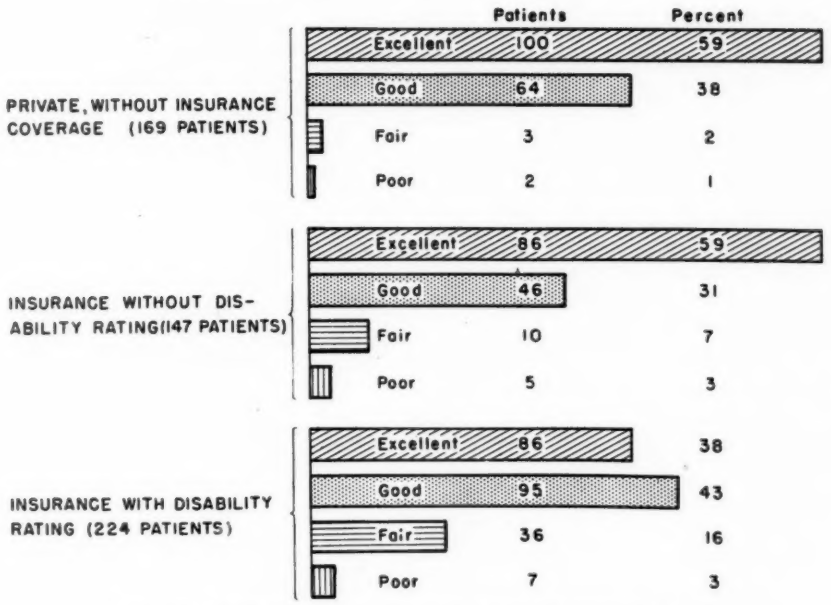

FIG. 13. Relationship of results to financial responsibility.

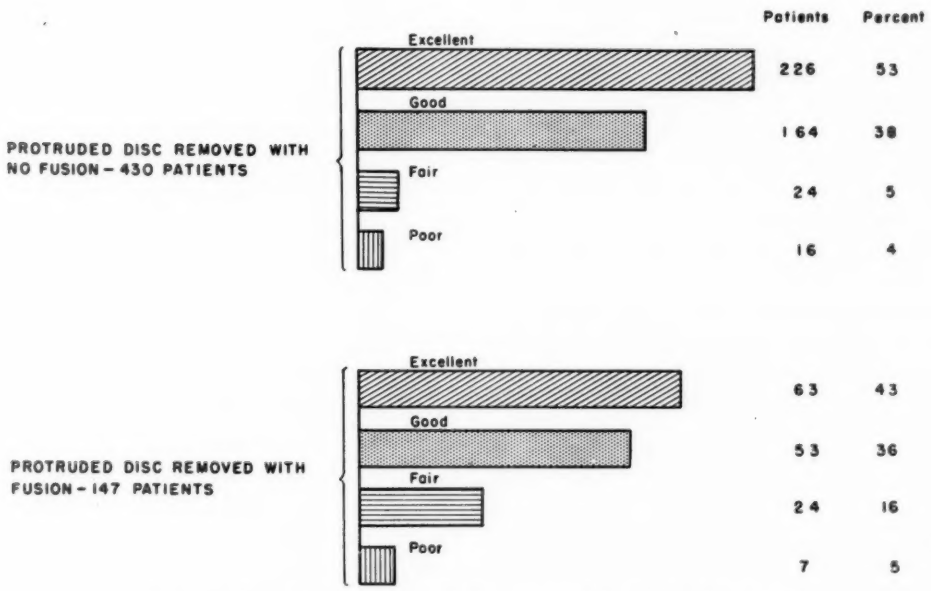

FIG. 14. Results of protruded disc removal and spinal fusion.

paid not only the hospital and doctor bills, but rated the patient for disability. As may be seen in Figure 13, the excellent and good results are approximately the same in those patients who paid their own bills and those whose bills were fully or partly paid by an insurance company. However, when there was a chance of financial gain in the form of a permanent partial disability award, the patient was inclined to claim less than an excellent result and more of the results fell in the good and fair categories.

An attempt has been made to evaluate the results of removal of the protruded disc alone and removal of the protruded disc combined with spinal fusion. Four hundred thirty patients were operated upon, the protruded intervertebral disc being removed and no fusion performed. (Fig. 14.) There were 53 per cent excellent results and 38 per cent good results. When a protruded disc was removed and fusion was performed (147 patients) the excellent and the good results were somewhat less. However,

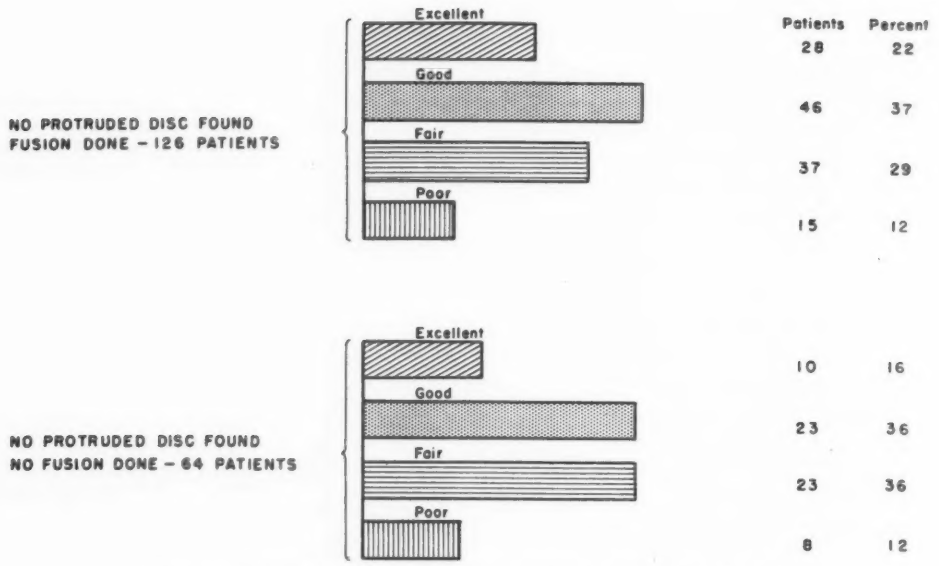

FIG. 15. Results of protruded disc removal and spinal fusion.

the assumption is that those patients who require fusion in addition to protruded disc removal have more back trouble than the patients with simple protruded discs, and therefore, the comparison is not entirely fair. In 126 patients in whom the exploration revealed no protruded disc but fusion was carried out, the excellent and good results were still less. (Fig. 15.) The poorest results occurred when no protruded disc was found and no fusion was performed. Over the last twenty years, 25.7 per cent of the patients from whom we have removed a protruded disc have had spinal fusions at the same time.

COMPLICATIONS

Nine hundred fifty-four operations were performed on the 905 patients. (Table II.) Thrombophlebitis occurred after five operations, lung abscess after one, and seven patients had wound infections. It was thought that pulmonary embolism occurred in two patients with non-fatal results. Two patients had ulnar neuritis. There were no deaths in the series.

TABLE II
COMPLICATIONS (905 PATIENTS—954 OPERATIONS)

Condition	No. of Patients
Thrombophlebitis	5
Lung abscess	1
Wound infection	7
Pulmonary embolus (non-fatal)	2
Ulnar nerve neuritis	2
Deaths	0

SUMMARY AND CONCLUSIONS

1. The case histories of 817 patients operated upon by me and eighty-eight patients operated upon by my associates for protruded lumbar intervertebral disc have been reviewed. Nine hundred fifty-four operations for protruded disc were performed upon these 905 patients.

2. In 76.2 per cent of 819 patients whose original operation was performed by us, protruded intervertebral discs were found. Five and a half per cent of the patients were found to have lesions about the nerve roots other than protruded lumbar intervertebral disc which seemed to be causing the symptoms. In 18.3 per cent of the group, no gross nerve root lesion was uncovered.

3. Single protruded discs were found in 610 patients and multiple protrusions in fourteen patients.

4. Ninety-six per cent of the lumbar protruded discs in this series occurred at the last two disc spaces.

5. The youngest patient operated upon in this series was eleven years old and the oldest was eighty-one. Sixty-eight per cent were between the ages of thirty and fifty. A fifth of the patients were female. Approximately 70 per cent gave a history of a definite back injury.

6. Symptoms, signs, laboratory and x-ray findings were reviewed in: (1) patients found to

have protruded discs, (2) patients with lesions of the nerve roots other than protruded disc, (3) patients in whom no gross nerve root lesion was found. In the three groups there were few significant statistical differences. A decrease in the Achilles reflex was found more often in patients with protruded disc at the L5–S1 space than in any other group. Decrease in the patellar reflex was found more often in patients with protruded discs at the L3–L4 space. Roentgenographic evidence of narrowing of a disc space cannot be relied upon as evidence of the presence of a protruded disc.

7. Our clinical judgment in the 905 patients based on evaluation of the symptoms, signs, laboratory and x-ray findings, exclusive of the Pantopaque test, was 82 per cent accurate in making the diagnosis of protruded lumbar intervertebral disc.

8. The Pantopaque test in 765 patients was proved to be 82 per cent accurate.

9. Our clinical diagnosis and the Pantopaque test were simultaneously correct in 72 per cent of 765 patients explored for protruded disc. Both were incorrect in seven per cent. In 11 per cent of patients the clinical opinion was correct and the Pantopaque study incorrect. The Pantopaque study was correct and the clinical opinion incorrect in 10 per cent.

10. The over-all results of surgery in the patients operated upon for protruded lumbar intervertebral disc were: excellent, 43 per cent; good, 37 per cent; fair, 14 per cent; and poor, 6 per cent.

11. In patients receiving compensation the results were claimed to be less satisfactory than in those not receiving a permanent partial disability award at the time their condition became stationary.

12. The best results were obtained when a protruded disc was removed and no spinal fusion was deemed necessary.

13. Complications were few following the 954 operations and there were no operative deaths.

DISCUSSIONS OF PAPERS BY DRS. THATCHER; AND RAAF

HAROLD CORNELIUS VORIS (Chicago, Ill.): I want to discuss Dr. Raaf's paper primarily, but I have a comment on Dr. Thatcher's paper.

From the standpoint of a specialist, it is very interesting to see that of 100 unselected patients with low back pain of industrial origin, only three turned out to have lumbar disc protrusions, at least, during the period of his observations.

I suppose that those of you who see these patients initially know more about this than I do, but it is well for the specialist who sees a proportionately large number of lumbar disc protrusions to keep that point in mind.

I want both to congratulate and thank John Raaf for this very fine paper. He courteously told me before the opening of the meeting that there was nothing new in his paper, nothing we did not already know. I do not think that that is true. If one carefully studies his paper, one will find a lot of interesting points and some things that one did not know before.

I was particularly impressed by the number of negative explorations in which the total protein was elevated over 40 mg. That parallels my own experience, and emphasizes the fact that there is no single laboratory or diagnostic procedure that will make the diagnosis of lumbar disc protrusion absolute. Then the tabulation of reflex changes was very interesting. While it is apparent, from an anatomical standpoint, that a large or extruded third lumbar disc may affect the fifth lumbar or first sacral nerve root and produce diminished ankle jerks, it is not so easy to explain how a fifth lumbar disc produces a diminished knee jerk in 9 per cent of the patients. I think that is too high a percentage to explain on the basis of coincidence and that variation in the innervation of the knee jerk must be the answer.

Dr. Raaf unfortunately did not have time, in his conclusions, to emphasize some of the points in the paper that I had the opportunity of reviewing. Perhaps the best argument for the use of myelography was apparent in his tabulation in which you will recall that there was a failure of both clinical and Pantopaque studies in only 7 per cent of the cases. Now this really makes it worth while, I believe, to combine Pantopaque myelography and clinical studies, in the majority of the cases, and this conclusion is one which I did not reach until recent years.

I would like to make a final remark about Dr. Raaf's results. He did not define his various categories. I think they are more or less apparent, and yet all of us who have attempted to fit our own patients into similar categories know that there are some difficult problems in connection with the individual case.

I do have some difficulty with my own cases, and I would like to ask Dr. Raaf what he would do, for example, with a patient who has good results from removal of a unilateral disc protrusion for three or four years, and then recurrent disc protrusion develops at a different level. Is this a good result for the period before the disc recurred, or is it only a fair result? It is a difficult problem for me and I would like Dr. Raaf's opinion.

NELSON J. HOWARD (San Francisco, Calif.):

I thoroughly enjoyed both of these papers, and I think I can appreciate the differing viewpoints from which the two were presented. Dr. Thatcher presents the view of the general or the industrial surgeon who sees frequent back injuries, acute back injuries, and being a good industrial surgeon, he has found only approximately two in 100 cases that we might call or consider the protruded intervertebral disc type of lesion.

Some fifteen years ago in a study of 250 cases of acute back injuries in much the same manner as Dr. Thatcher has stated in his cases, I found only two that would fit in the very rigid classification of the acute disc lesions. These two patients were operated upon by an excellent neurosurgeon with whom Dr. Raaf is acquainted. One had close to a 100 per cent recovery. He returned to his former occupation, and without a disability rating. His occupation was sedentary in a bank. The injury had resulted from a slip and a fall. He had had a previous history of back strain occurring in his home.

The second case was a 100 per cent failure. This patient had had a neurological operation, and as far as relief of the disc was concerned (being only a general surgeon and not a neurologist or neurosurgeon), I believed that the lesion was between the second and third lumbar spine because of certain clinical and radiological signs. The very good neurosurgeon whom Dr. Raaf knows in San Francisco operated upon this patient, took out the contents of the nucleus pulposus between the fourth and fifth and then between the fifth and first sacral vertebral bodies. I talked to him prior to the operation about the lesion being higher up. When I called him about the results afterwards, when the patient was returned to me, he simply said: We find 95 per cent of our cases of trouble between those two bodies, in that area (the fourth and fifth and fifth and first), so we did not bother to go higher up. We thought she would be cured.

I do not know whether he is a lazy surgeon or not. I myself am regarded as a lazy surgeon. I would rather cure a patient without an operation if I can. In California rather than in Milwaukee, Wisconsin, instead of paying off in money for final disability rating, we try to pay off in happiness. I think this is the attitude in California, and as a lazy surgeon I would rather have happiness and leisure and not have to operate as much.

Now Dr. Raaf has presented a great many cases and he states that in the final synopsis he has many more on which to report. Dr. Raaf has learned the methods of New York and Chicago. Just as the Braves in Milwaukee have a string of farm teams for their baseball team, he has a string of country practitioners who send him their cases, or he goes to the country practitioner and operates in his home town. I think this is fine.

I have known Dr. Raaf since he was in high school. I have admired him since he was welterweight champion of the Pacific Coast in the collegiate circles. I admire him as much for his surgery and honesty as well as his policy. He never threw a fight, and he is honest in his presentation of figures.

I would like to say one thing in regard to the pathology he describes. He disregards changes in the ligamentum flavum, changes in the accessory ligaments, and speaks only about the nucleus pulposus nerve lesions and the disc itself.

Robert H. Kennedy (New York, N. Y.): Has Dr. Raaf changed his indications for operation at all as a result of this beautiful analysis?

Paul H. Harmon (San Francisco, Calif.): I want to confine my remarks to Dr. Raaf's paper. This paper is, of course, a presentation of results by a man who is skilled and specialized in the field. These results and those of other men devoting themselves exclusively to this kind of work are excellent as contrasted to those of the occasional operator.

I am intrigued by Dr. Raaf's statistical analysis of classic symptoms and findings of disc protrusions at different levels. The missing knee jerk is said to indicate a lesion between L3 and L4 and the missing Achilles jerk is associated with a lesion between L5 and S1. Dr. Raaf has demonstrated a missing Achilles jerk due to the pathologic condition of various levels.

I am a little surprised that Dr. Raaf has not had more recurrences and instances of persistent radicular pain. Everyone has had a certain number of patients who have had complicating contralateral radicular pain following removal of discs. I am anxious to know, in Dr. Raaf's series, how he has classified a patient who is free of pain for several months or years, and then has a recurrence of radicular pain at the same or another level. Is that a good or bad result or how is it classified?

The experience quoted by Dr. Raaf concerning the question of financial responsibility has been shared by everyone in this field. In the State of California, we have a six-month state administered sickness disability, and therefore the most popular period of disability in the State of California is six months.

Edgar L. Gilcreest (San Francisco, Calif.): I congratulate Dr. Thatcher on his analysis of 100 cases of low back pain. I am surprised that no one has mentioned manipulating these patients. I refer particularly to the cases presented by Dr. Thatcher. While I do not think that manipulation is going to cure a dislocated disc, I still believe that the situation of many of these patients can be improved if they are properly and early manipulated.

I refer you to an article entitled "Lumbosacral and Sacro-Iliac Strain Causing Low Back Pain" by me which was published in the *Annals of Surgery*,

(107: 988, 1938) in which I discussed the methods of these manipulations which I have found most beneficial.

DONALD S. THATCHER (closing): I very much appreciate the kind comments of Drs. Voris and Howard. There were three patients who came to laminectomy for disc in this series, and if you will recall, there were an additional four patients in whom orthopedic consultation confirmed the clinical impression of herniated intervertebral disc, and laminectomy was advised but was not accepted by the patient or was not carried out.

In response to Dr. Gilcreest's point, I personally have had no experience and no training in manipulation, and therefore, have not employed it. This does not imply, of course, that I do not approve of it.

The important point, to my way of thinking, in reviewing these 100 unselected patients as they presented themselves to me was that it brought home the fact that the length of treatment can be anticipated as being twice as long and the length of disability three times as long in the patient if the x-ray films of the back show a demonstrable pathologic condition at the time the patient presents himself for treatment, and that permanent disability will result only in those patients with positive findings on x-ray examination. Furthermore, the surgeon carries a, by no means, small responsibility in his approach to these patients since each of these patients represents a potential cost to the employer of $1,214.91. In this figure there is no fee allowed or calculated for the surgeon's initial treatment and care since these patients are all treated by me on a retainer fee for one of the large corporations.

JOHN RAAF (closing): Dr. Voris has asked how I would classify a patient who apparently has a good result for a few years and in whom a protrusion at another level or a recurrence at the same level then develops. This is a difficult question and we spent a great deal of time trying to classify some of these patients. Probably the time interval between operation and recurrence was the major factor in classification. For example, if a patient had freedom from symptoms for ten years or more following operation, and another protrusion then developed, either at a different level or at the same level, we would be likely to classify the result as excellent or good. If only a few months elapsed before there was a recurrence at a different or the same level, we would classify the result as fair or poor.

Dr. Howard brought out the point that a Pantopaque study should be made before operation in all cases of protruded disc. One can not as far as I can tell, absolutely determine the level of a protrusion from the neurological examination, even though we know most protrusions occur at one of the last two levels.

Dr. Kennedy has asked whether as a result of this study I had changed my opinion regarding operation upon patients with protruded disc or had in any manner changed the operative procedure. I think that this analysis has made me disregard some neurological signs that I formerly thought were important. The study has led me to believe that Pantopaque studies should be made in practically 100 per cent of the patients with discs prior to operation. I have never seen an important complication from a Pantopaque study. In some patients, of course, headaches from spinal puncture do develop, but I have never seen an infection or any other untoward result that I thought was brought about as a result of the Pantopaque study.

I think possibly that as a result of this study I am a little less enthusiastic about spinal fusion in conjunction with removal of protruded intervertebral disc than I was at one time. One chart I did not have time to show, brings out how our enthusiasm has waxed and waned regarding spinal fusion in conjunction with protruded disc operations. In the twenty years we have been performing operations for protruded discs, 27 per cent of the patients had spinal fusions at the same time the protrusion had been removed. I recently talked to one of the neurosurgeons at the Mayo Clinic, and he said he thought they were carrying out fusions in conjunction with disc removals in about 50 per cent of the cases.

Dr. Harmon mentioned patients with persistence of radicular pain following operation. We have those patients, too, and those are the ones that were categorized as good and fair results, rather than excellent results. A result was considered excellent when the patient was entirely back to normal.

I agree with Dr. Gilcreest that manipulation is well worth trying in these patients. We rarely operate upon a patient for protruded disc within the first two months after disc symptoms have developed. We try all sorts of conservative measures including traction, manipulation and physical therapy before advising surgery unless the symptoms are so acute and severe that we fear permanent neurological defects if operation is not performed early.

The Need for an Active Teaching Program in the Emergency Service

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THE primary function of the Emergency Service at the Illinois Research Hospital is to provide the house officers and medical students with experience in the diagnosis and management of trauma and medical and surgical problems of the acute type. Our experience is somewhat unique in that while situated in a large medical center we are forced by a limited bed capacity to be moderately selective in the type of patient admitted. Most of the traumatic cases are brought in by the Police and Fire Departments, which provide the city with ambulance service.

The Emergency Service is located at ground level with the entrance at the foot of an ambulance drive clearly marked leading off a main thoroughfare. The floor plan of the unit is shown in Figure 1. In addition to several examining rooms there are a nurses' station, doctors' office, laboratory, small x-ray unit and two completely equipped operating rooms. One room is equipped with a refrigerator and coffee makers, and is used by both policemen and students for informal conferences. Two wards with two beds each are most helpful for overnight observation of patients for whom immediate hospitalization is not required.

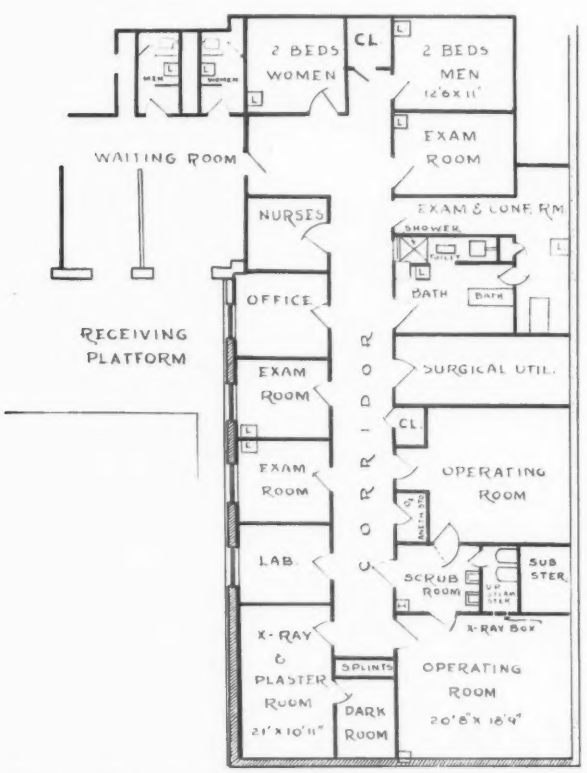

FIG. 1. Floor plan of the Emergency Service at the Illinois Research Hospital. The unit contains several examining rooms, a nurses' station, doctors' office, laboratory, an x-ray room and two operating rooms. Two wards with two beds each are most helpful for overnight observation of patients.

PLAN OF ORGANIZATION

Personnel. It is important that some member of the staff be appointed chief of the service and be concerned with the various administrative and medical problems which arise. If, for instance, one of the younger members of the surgical staff is the chief, he may drop in several times a day and help in establishing a diagnosis for an acutely ill patient; he may solve a difficult disposition problem or demonstrate good technique in suturing a severe laceration. The chief of the service must be sure that each hospital department provides adequate coverage twenty-four hours a day and that calls for assistance are responded to promptly.

At the Illinois Research Hospital three interns are assigned to the Emergency Service each month and rotate through eight-hour shifts. During peak periods such as Friday, Saturday and Sunday nights, a second call intern is in the hospital and keeps in close touch

with the physician on duty. A resident physician from each department is on call at all times for consultation and the intern is encouraged to call him for all significant problems. The resident must call an attending physician for complicated cases or for those patients requiring a major operation.

A well trained nurse supervisor and a small but efficient staff of registered and practical nurses, clerks and orderlies are also necessary for a smoothly functioning unit.

Emergency Service Manual. The constant rotation of interns and residents creates a problem in maintaining high standards of treatment. We have found it helpful to compile a manual, the table of contents of which is listed in Table 1. The General Rules include short paragraphs on points such as precautions in asepsis, consent for operation, narcotics, animal bites, etc. The "Ten Commandments" are fundamental points in the treatment of seriously injured patients. Sections III and IV are concerned with the examination, evaluation and initial treatment of acutely ill or injured patients. Subsequent sections cover the points as listed, i.e., scrub technique, preventive treatment of tetanus, etc. Before the interns go on service, each is given a manual and the contents are reviewed with them. Other problems such as the medicolegal aspects of treatment and the management of patients with multiple injuries also are discussed. In addition to our own directives, the monographs on soft tissue injuries and fractures prepared by the American College of Surgeons' Committee on Trauma [2,3] are most helpful.

Teaching Program. One of our responsibilities is to teach the care of the acutely ill or injured patient to the students. Two or three senior students are on duty from 6:00 P.M. until midnight each evening, and each student will have four to six such periods during the quarter he is on the surgical service. We also cooperate with the Medical Education for National Defense Program by giving formal lectures on trauma problems to the freshman students. One or two freshman students are assigned to the Emergency Service as observers each night. Since in the event of national disaster dentists will have to be familiar with the basic principles of emergency care, one of the dental students is assigned to the Emergency Service each night as an observer.

Public Relations. There are several ways in which we attempt to maintain good relations with the community and with local and downstate physicians. Our former policy was to refer all requests for information to the Public Relations Department. However, it is more expedient to have the physician on duty furnish basic factual data such as the extent of injury and condition of the patient. All patients coming to the Emergency Service are asked if they have a family physician. If the patient does have a doctor but still desires treatment, a report of the injury and treatment is immediately sent to his physician. The patient is then referred back to his doctor for continuing care.

Another problem frequently encountered is the arrival of a patient via ambulance from 200 or 300 miles away with no previous arrangement for admission to the hospital. We make every effort to admit these unfortunate persons. However, at times no bed is available; in such a case we may keep the patient in an observation bed overnight until some disposition can be made the following day.

Disaster Planning. In the event of a local or city-wide disaster the Emergency Service would be first to receive casualties. Our hospital disaster plan is set up on this basis with provision for routing overflow casualties directly to the X-ray Department, operating rooms, surgical dispensary, etc., from a triage center near the emergency entrance. The emergency unit would then be reserved for initiating treatment to patients in shock or those needing resuscitation or other life-saving measures.

Recovery Room. Full use of the recovery room is made in that acutely injured patients are frequently taken from the emergency suite to the operating room and then to the recovery room, although technically they are admitted

TABLE 1
EMERGENCY SERVICE MANUAL
TABLE OF CONTENTS

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	Introduction	1
Section I.	General Rules	2
Section II.	"Ten Commandments"	6
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TABLE II
ILLINOIS RESEARCH HOSPITAL EMERGENCY SERVICE
ANNUAL REPORT, 1957–1958

Total No. of patients seen in Emergency Service		15,841
Per cent traumatic		18.2%
Admissions to hospital from Emergency Service	1,326	
Surgery		365 (27.5%)
Medicine		247 (18.6%)
Gynecology		164 (12.4%)
Obstetrics		75 (5.6%)
Pediatrics		243 (18.3%)
Neurology		53 (4.0%)
Orthopedics		153 (11.5%)
Psychiatry		1 (.07%)
Ophthalmology		7 (0.5%)
Otolaryngology		18 (1.4%)
Obstetrical patients	2,090	
Patients discharged	7,725	
Health Service	636	
Active clinic patients	1,673	
Patients sent to other hospitals	354	
Biopsies	11	
Blood transfusions, parenteral fluids	56	
Observation bed patients	651	
Miscellaneous	1,286	
Deaths	13	
Dead on arrival	20	
Patients referred back to private physicians		925 (5.8%)

to the surgical ward. The neurosurgical service finds it helpful to be able to send a patient with a severe head injury directly to the recovery room for close observation until the need for operation has been settled. A similar procedure is followed for patients with severe multiple injuries; the service treating the most severe injury is directly responsible for the patient's management and for requesting consultation for other injuries.

Analysis of Patient Load. During the twelve-month period of July 1, 1957 to June 30, 1958 a total of 15,841 patients were seen in the Emergency Service, an average of 1,320 per month. Of this total, 1,326 patients were admitted to the hospital, representing 8 per cent of all patients seen. A detailed record is made each month of all types of patients treated and this forms the basis of our annual report, a copy of which is shown in Table II. It may be noted that 18.2 per cent of all patients treated had traumatic problems such as lacerations, fractures and injuries to the head. We also record the number of direct hospital admissions by departments and it may be seen that a significant number went to the medical and pediatric services. The Emergency Service performs ancillary services such as biopsies, blood transfusions, etc., which help to conserve hospital beds. Record is also kept of the number of patients referred back to their family physicians for continuing care. The number of trauma patients treated and type of injury are listed in Table III. The number of patients arriving with significant multiple injuries during the past year totaled 8.6 per cent of all trauma patients. Approximately 20 per cent of the trauma patients had injuries to the head of varying degrees of severity. Those with severe injuries were hospitalized but the less serious cases often presented a difficult problem as to management. In general, we keep those patients under observation for several hours and obtain x-ray films of the skull prior to their discharge.

THE NEED FOR ACTIVE SUPERVISION

We are convinced that in addition to active supervision of the emergency unit by the chief of the service, consultation with senior members of all departments of the hospital staff must be readily available. Patients sustaining severe injuries to several organ systems may tax the judgment and skill of the most experienced physicians, and repeated consultation is often needed to outline the best methods of treatment. Examples of such problems are presented hereafter.

CASE 1. (*Multiple fractures complicated by pneumothorax and abdominal injury.*) A white woman, age sixty, was admitted to the Emergency

TABLE III
ILLINOIS RESEARCH HOSPITAL EMERGENCY SERVICE
ANNUAL REPORT, 1957–1958
Trauma Cases

	No. Cases	Per cent
Lacerations	1,842	58.8
Fractures	331	10.6
Injuries to head	646	20.6
Injuries to chest	161	5.1
Injuries to abdomen	57	1.8
Burns	95	3.0
Total	3,132*	....

* Patients with multiple injuries (severe), 248 or 8.6 per cent.

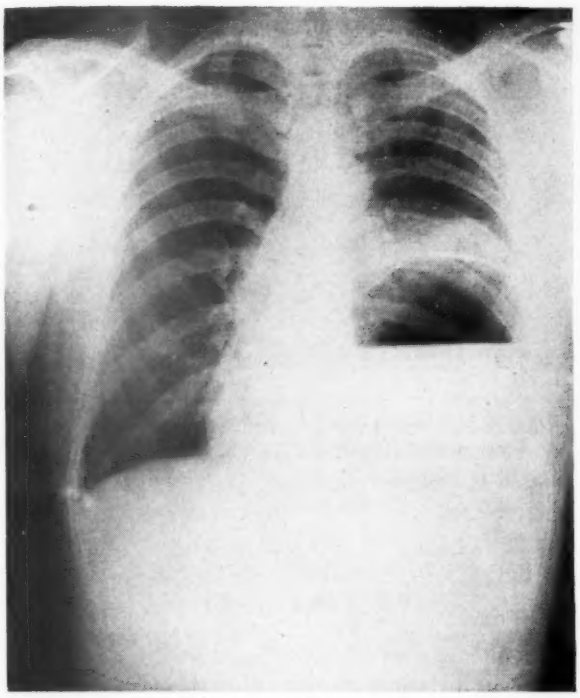

FIG. 2. Case II. Chest x-ray film of thirty-four year old Negro man taken shortly after admission to the Emergency Service following an automobile accident. The patient complained of pain in the chest, abdomen and over the pubis. Breath sounds were decreased on the left side. X-ray examination of the pubis showed fractures of the pubic ramus and ilium on the left.

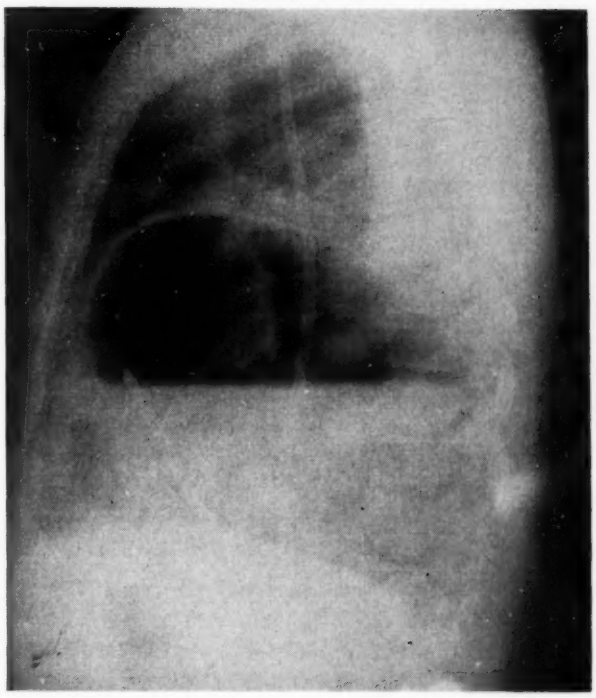

FIG. 3. Case II. Lateral chest x-ray film following passage of a Levin tube. The breath sounds were absent and there was dullness to percussion over the left side of the chest. The large air-fluid level is in the stomach which has herniated into the chest through a traumatic rupture of the left diaphragm.

Service half an hour after being struck by an automobile. She was conscious but pale and listless. The pulse was 120 and blood pressure 100/50 mm. Hg. Examination revealed an open fracture of the middle third of the left tibia and fibula, and an open supracondylar fracture of the left femur. The patient also had fractures of the left eighth and ninth ribs and a left pneumothorax. Following correction of the pneumothorax by thoracentesis, a general anesthetic was given and the wounds were débrided. The tibial fracture was reduced and Steinmann pins were placed proximal and distal to both the tibial and femoral fractures, and incorporated in a leg spica cast. During the next twenty-four hours the patient's pulse remained rapid and the blood pressure low despite several blood transfusions. Increased abdominal muscle spasm was noted and a needle aspiration, performed because of suspected intraperitoneal bleeding, showed bright red blood. At celiotomy there was a considerable amount of liquid and clotted blood in the abdomen due to a laceration of the lower pole of the spleen. There was evidence of contusion of the left kidney. Splenectomy was performed without incident. Postoperatively the patient remained febrile and pulmonary rhonchi were present. On the third postoperative day examination of the urine revealed fat globules. The patient gradually improved and finally was discharged about two months after the accident still in the hip spica. The patient was readmitted about five months after injury for removal of the cast and pins. X-ray films showed satisfactory healing of the femur but apparent delayed union of the tibia. A long leg cast was applied and the patient was to be followed up in the orthopedic clinic. X-ray films of the left leg taken eight months after the injury showed definite delayed union; however, within one year after injury definite callus had formed and the patient was bearing full weight with the aid of a crutch.

Severe multiple injuries of this type present difficult diagnostic problems, and in retrospect it appears that the lacerated spleen accentuated the shock and probably should have been removed soon after the original injury. The diagnosis also was complicated by the left pneumothorax and the moderate contusion of the left kidney found at celiotomy.

CASE II. (*Traumatic rupture of diaphragm and fractured pelvis.*) A thirty-four year old Negro man was admitted to the Emergency Service about 6:00 P.M. because of injuries sustained in an automobile accident. He had been riding in the back seat

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FIG. 4. Case II. A left thoracoabdominal incision revealed that the stomach and part of the transverse colon had herniated into the chest through a rupture of the central portion of the left hemidiaphragm. D = diaphragm; C = colon.

FIG. 5. Same case. Following reduction of stomach and colon back into the abdomen a large defect of the central portion of the diaphragm was repaired with interrupted No. 2-0 silk sutures. D = diaphragm.

but did not remember whether he had been unconscious. On admission the blood pressure was 90/70 mm. Hg, pulse 88 and hematocrit 40 per cent. Physical examination revealed decreased breath sounds over the left side of the chest, tenderness over the upper portion of the abdomen and tenderness over the pubis. X-ray films showed fractures of the left pubic ramus and ilium and an apparent elevation of the diaphragm on the left. (Fig. 2.) Following administration of 1,000 cc. of dextran the patient's blood pressure rose to 110/70 mm. Hg. He preferred to sit up in bed, and complained of pain in the left side of the chest and the flank. At 4:00 A.M. breath sounds were still absent over the left side of the chest and there was dullness to percussion. The urine, which had been clear initially, now had many red blood cells per high power field. An attending surgeon was called to see the patient and suggested passing a Levin tube and repeating the chest film. It was now obvious that the patient had suffered a traumatic rupture of the diaphragm with herniation of the stomach into the left side of the chest. (Fig. 3.) The patient was taken to the operating room and through a left thoracoabdominal incision the stomach and transverse colon were found to have herniated through a rupture of the left hemidiaphragm. (Fig. 4.) A small laceration of the left lobe of the liver and contusion of the lower abdominal wall were also seen. The liver laceration was sutured, and after reduction of the stomach and

FIG. 6. Case III. View of transverse colon and greater omentum of white man aged fifty-one, who had been struck in the abdomen by a steering wheel. No pulse or blood pressure was obtainable upon entry. Celiotomy revealed bright red blood filling the entire abdomen due to a ruptured middle colic artery. The mid-portion of the transverse colon was cyanotic. O = omentum; C = colon.

FIG. 7. Case III. View of transverse mesocolon, showing large hematoma due to rupture of the middle colic artery. Cyanosis of the transverse colon improved following packing with warm laparotomy pads, after which a mid-transverse colostomy was performed.

colon the diaphragm was repaired. (Fig. 5.) The patient's postoperative course was not remarkable and he was discharged ambulatory on crutches because of the pelvic fracture ten days after injury. Five days later the patient was readmitted because of fever and pain in the left chest. An x-ray film showed a moderate amount of fluid in the chest and there was a cystic area under the chest incision. Thoracentesis was attempted but unsuccessful; however, there was a spontaneous discharge of a small amount of serosanguineous fluid from the old chest tube drainage site, following which the patient's fever subsided and the pain disappeared.

This is another example of a patient with multiple injuries in which the most severe injury was not recognized immediately. Because of his age and excellent health, the twelve-hour delay was not serious. However, in an elderly patient or one with additional injuries the outcome might have been less favorable.

CASE III. (*Blunt trauma to the abdomen.*) A fifty-one year old white man was brought to the Emergency Service five hours after involvement in an automobile accident in which the steering wheel had struck his abdomen. On entry no pulse or blood pressure was obtainable. Two units of a plasma expander were given, followed by the transfusion of whole blood. Seven units of blood were required to bring the systolic blood pressure to 100 mm. Hg, at which time celiotomy was performed. On entering the peritoneal cavity through a left paramedian incision, a large amount of bright red blood was encountered and aspirated. The source of bleeding was a ruptured middle colic artery which was spurting vigorously. The transverse mesocolon was swollen and ecchymotic, and the transverse colon was very cyanotic. (Figs. 6 and 7.) No peristalsis was observed in the cyanotic segment. At this point the resident surgeon planned to perform a resection of the contused colon with exteriorization of the proximal and distal ends. Consultation with an attending surgeon was requested and it was decided to pack the cyanotic bowel with warm laparotomy pads and to observe it for a time. The color soon improved perceptibly and a transverse colostomy was performed. The patient required an additional unit of blood after operation, and because of the prolonged hypotension prior to operation intravenous hydrocortisone was given.

Postoperatively the patient was febrile with an elevation to 102.4°F. on the second postoperative day, probably due to pneumonitis and some atelectasis. The fever gradually subsided and the patient was discharged on the seventh postoperative day. Subsequently he was admitted for closure of the colostomy, which was tolerated without incident.

This case history illustrates efficient management of a patient with severe hemorrhage following blunt trauma to the abdomen. The operation of choice, however, was not so clear. It is quite possible that the added operating time and trauma of a colonic resection might have altered the favorable outcome in view of the somewhat complicated postoperative course. We believe that the resident staff should have the advantage of consultation with an easily available attending surgeon at any stage in the management of acutely ill or injured patients.

SUMMARY

The Emergency Service is now an integral part of almost every hospital and seems to be occupying an increasingly prominent part [4] in the treatment of acutely ill and injured patients. Careful thought as to the location, physical plant, organization and supervision of such a unit are essential to a smoothly functioning service. We believe it is important that one of the staff members be appointed chief of the service and be actively concerned with its function. A small but well trained staff of nurses, clerks and orderlies is essential for an efficient unit. A set of directives which may be incorporated into an emergency service manual is helpful in establishing basic rules for the handling of constantly recurring problems. In addition to serving the community by providing efficient treatment of the acutely injured patient, the Emergency Service provides experience in the treatment of trauma to staff physicians, house staff and students, and is useful in improving public relations with the community and local physicians. The unit usually occupies a prominent part in the hospital disaster plan as the reception area for triage and treatment of casualties. Analysis of the number and type of patients treated may reveal a surprisingly large percentage of medical and pediatric patients, many of whom require admission to the hospital. It is mandatory that senior members of the hospital staff from the various specialties be available for consultation when needed, and that there be an active supervisory program. Severe injuries such as multiple fractures associated with injuries to the chest and abdomen, injuries to the head complicating the management of associated fractures, etc., and blunt trauma to the chest and abdomen may tax the most experienced physicians. A few

examples of such problems have been reviewed to substantiate the need for active supervision in the emergency unit.

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The Expired Air Ventilator

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THIS paper describes a convenient technic for artificial respiration of apneic or depressed patients during their transport or examinations in crowded quarters. By a compact, simple apparatus the nurse, physician or trained attendant may breathe for the patient in the ambulance, corridor, elevator, x-ray room or ward. Since the expired air of the attendant serves as the ventilating gas, the encumbrances, hazards and supply problems of compressed oxygen are eliminated. The apparatus, called the expired air ventilator, may be used with oronasal mask, tracheal tube or tracheotomy. When the patient's airway is reliably established with a cuffed endotracheal tube, the hands of the attendant are free to assist in transportation by cart or hospital bed, to open elevators and doors, to take pulse and blood pressure, to manage intravenous and drainage equipment, and occasionally to help restrain the convulsive or hyperactive unconscious patient. Foremost among the advantages of the expired air ventilator is the additional sensory perception available to the attendant as a breath by breath monitoring of the pulmonary ventilation he is delivering to the patient. Not only can he see the chest expand, but also he can automatically sense changes in the ease of inflating the patient by his own respiratory pressure receptors and proprioceptors. This communication will deal with a description of the expired air ventilator and pertinent physiological measurements which established its safe use.

APPARATUS

The expired air ventilator is a derivative of the mask-to-mask resuscitator developed for military use in connection with the treatment of severe respiratory casualties. The attendant and patient are coupled by means of a flexible breathing tube of the type used in anesthetic or basal metabolism machines. (Figs. 1 and 2.) At the attendant's end of this breathing tube is fitted a comfortable mouthpiece and, optionally, a wire support which secures the position of the mouthpiece near the attendant's mouth. This support is a wire loop around the attendant's neck and is helpful when he must momentarily interrupt breathing for the patient, e.g., talking, coughing, sneezing.

The flexible breathing tube has a volume of

FIG. 1. Diagram of the expired air ventilator in use showing a flexible rubber breathing tube connecting a mouthpiece for the operator to the valve assembly which is coupled to the endotracheal tube for the patient. A neck loop provides support for the mouthpiece.

FIG. 2. Expired air ventilator connected to an endotracheal tube.

300 ml. which serves as an external dead space imposed upon the attendant but not upon the patient. Thus the intake port is at the patient's end of the breathing tube. The inflation comprises an initial 300 ml. of ambient air, an additional 100 to 150 ml. of ambient air which represents the physiological dead space of the attendant, and sufficient alveolar air of the attendant to produce visible expansion of the patient's chest.

Two valve assemblies are placed at the patient's end of the breathing tube. The first, a simple intake port for ambient air, is valved to close during inflation of the patient's lungs. (Fig. 3.) This directional valve permits the patient to inspire ambient air on demand should he breathe out of phase with the attendant. The second assembly, a double-acting valve, consists of another directional valve mounted in a mobile seat or flexible diaphragm. One action of this assembly occurs during lung inflation when the diaphragm closes the patient's expiratory circuit and the attendant's expired air enters the patient's airway and lungs. The second action, which occurs as soon as the attendant terminates inflation to take his next breath, releases the flexible diaphragm and allows the patient's passive exhalation to be discarded. It is important for the attendant deliberately to time his next inspiration promptly after an adequate inflation is delivered to the patient in order to release pressure on his side of the diaphragm and permit the patient to exhale. Thus the attendant breathes with a deliberate inspiratory effort and with expiratory efforts coordinated with visible expansion of the patient's chest. In this manner the valving of the expired air ventilator allows the patient to exhale or breathe on his own while the attendant inhales. No complex coordination of skills is required of the attendant.

The 300 ml. dead space of the breathing tube is exploited in the patient's behalf. Several advantages of this exploitation of dead space are apparent in the measurements to be reported. Oxygen content and total volume of the attendant's expirations evaluate the suitability of the method so far as the patient is concerned. In two studies, arterial oxygen saturations of two anesthetized patients were determined during sustained use of the expired air ventilator by the exercising attendant.

The attendant, on the other hand, rebreathes with each cycle 300 ml. of his alveolar air from the breathing tube. His alveolar carbon dioxide levels are of interest to assess his tolerance of the respiratory task and the incidence of the development of hypo- or hypercapnia. When a compensatory increase in tidal volume results from this CO_2 rebreathing, the reflex hyperventilation is a physiologic asset for the method. Respiratory adjustments of individuals who exercised while using the expired air ventilator were studied to determine the suitability of the 300 ml. dead space, the competence of the

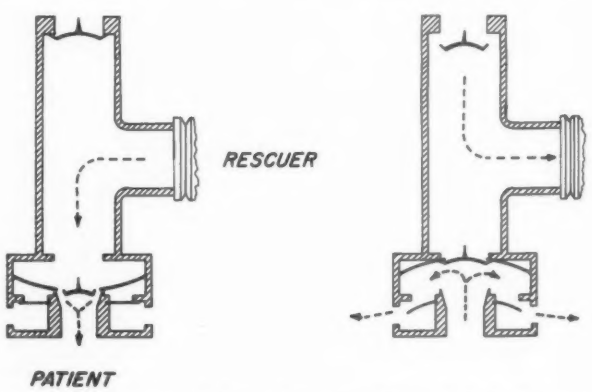

FIG. 3. Diagram of the valve assemblies. *Left*, inflation; *right*, passive expiration.

double-acting valve, and the performance of the attendant in using the expired air ventilator to ventilate a model with an external impedance comparable to a severely bronchoconstricted patient.

Gas Exchange. Proper exchange of oxygen and carbon dioxide with expired air resuscitation depends on hyperventilation by the rescuer and therefore hyperventilation by the patient. Further assurance that gas exchange will be adequate stems from the 300 ml. dead space in the rebreathing tube which connects the operator's mouthpiece with the double-acting valve. We have carried out studies on the efficacy of this arrangement in anesthetized, curarized subjects [2]. The gas exchange provided is completely adequate as judged by measurement of as many as 9 parameters. These included the alveolar oxygen and carbon dioxide concentrations of both the patient and the operator, the arterial oxygen concentration by oximeter and by direct sampling, arterial carbon dioxide tension and pH, air flow and tidal volume. These results all indicated the reliability and efficiency of the method, its tolerance of wide variations in rate, and the particular effectiveness of large tidal volumes.

The performance of seven subjects was evaluated while exercising and using the expired air ventilator on a lung model. The lung model simulated a severely bronchoconstricted patient [1]. The test subjects were normal male volunteer medical students and physicians varying in age from twenty-one to forty-two. Measurement of ventilation, oxygen consumption and tidal volume was made by collection and analysis of expired air. Alveolar gas concentration was measured by means of a Rahn end-expiratory sampler, a Cambridge hot-wire CO_2 analyzer, and a Beckman oxygen meter. The CO_2 analyses were also checked with a Liston-Becker infra-red CO_2 analyzer.

Initial measurements were made after a fifteen- to thirty-minute rest on a bicycle ergometer. Some subjects were fasting; others had recently eaten. Exercise was performed by bicycling at either 25 or 50 complete pedal revolutions per minute, timed with a metronome. The slower rate of exercising was the equivalent of 280 kg.m./minute, or about 2,000 ft. lb./minute. This is roughly equivalent to a man climbing stairs at the rate of one flight per minute. Dead space breathing was performed uniformly by the introduction of an extra 300 ml. of dead space in the circuit, which without it had 50 ml. of dead space. Expiratory resistance was introduced into the expiratory circuit by means of a two-hole rubber stopper. The pressure drop across this resistance was about 5 cm. of water at 0.5 L./second flow, and 20 cm. of water at 1.0 L./second flow. Seven subjects were observed at rest, during exercise, during exercise with added dead space, during exercise with added dead space and added expiratory resistance, and during exercise with added expiratory resistance but no added dead space. These observations were made consecutively although not always in the same order. No observations were made until the subject had been exercising at least ten minutes, and data were then collected over a three- to five-minute period. If exercise was not continuous, ten minutes of warm-up was used after each rest to reattain a fairly steady state.

The individual values for the seven subjects are shown in Figure 4. At rest the alveolar oxygen tension ranged between 108 and 120 mm. Hg, and the alveolar carbon dioxide concentration ranged between 4 and 5.5 per cent. With exercise without an added dead space there was a tendency for the alveolar oxygen to fall slightly and for the alveolar carbon dioxide to rise slightly. When the dead space was added,

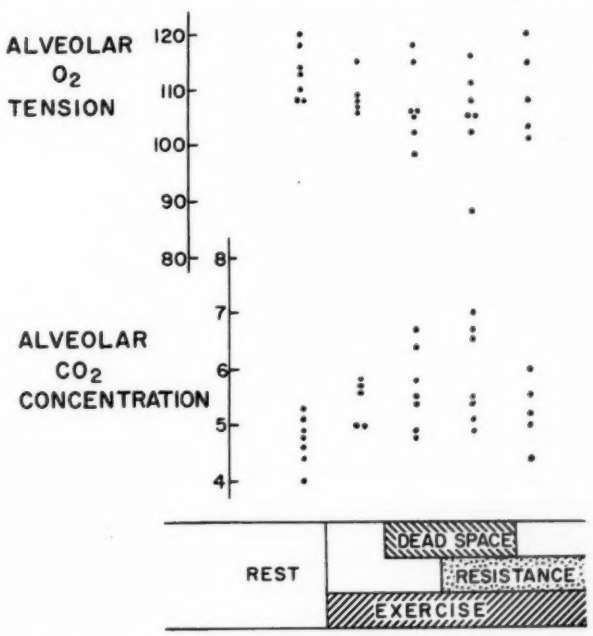

FIG. 4. Alveolar air oxygen tension (mm. Hg) and alveolar air carbon dioxide concentration (%) in seven subjects studied at rest, during exercise, and with added dead space and expiratory resistance separately and together during exercise.

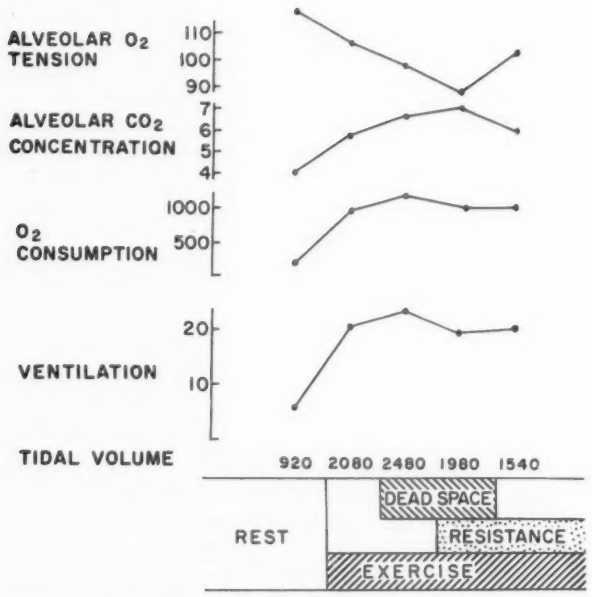

FIG. 5. Alveolar air oxygen tension (mm. Hg) and carbon dioxide concentration (%) in one subject during conditions as described in Figure 4. Also shown are the oxygen consumption (ml./minute), total ventilation (L./minute) and tidal volume (ml.).

this tendency was accentuated in some subjects, but all subjects were able to complete the task without great alteration in alveolar gas values or undue subjective distress. All but one alveolar oxygen tension remained above 100 mm. Hg and all alveolar carbon dioxide tensions remained below 7 per cent. Oxygen consumption was tripled with exercise and nearly quadrupled with exercise plus dead space. The tidal volume was doubled and tripled under similar circumstances. These figures give an approximation of the severity of the work load demanded of each subject. The conclusion from these data is that during exercise with a 300 ml. dead space the ventilating gas produced is somewhat less favorable than that produced at rest, but the resulting alveolar gas concentrations for the operator do not exceed the normal range and are not accompanied by intolerable symptoms.

When the expiratory resistance was added to the apparatus while the dead space was retained and the exercise continued, some subjects showed further rises in alveolar carbon dioxide concentration (the highest reaching 7 per cent) and one subject showed a further fall in alveolar oxygen tension to 88 mm. Hg. Despite these changes all but one subject could continue the work load for a full fifteen minutes. When the dead space was removed, the work of overcoming the expiratory resistance was tolerated much better and there was a corresponding tendency for improvement in the alveolar gas values. The oxygen consumption and tidal volume were further increased with the addition of the expiratory resistance as compared with the values obtained during exercise with the added dead space. When the dead space was removed, there was a corresponding fall in both oxygen consumption and tidal volume.

The most unfavorable reaction to these stresses is summarized in Figure 5, which gives the data obtained in the oldest subject. The changes in oxygen consumption and tidal volume are a guide to the severity of the stress. The alveolar oxygen tension fell steadily from the resting state with the addition of exercise, exercise and dead space, and exercise plus dead space plus expiratory resistance. Nonetheless this subject was able to complete the most difficult work and subjectively felt ready to continue for another fifteen minutes after the fifteen-minute period of severest work was completed.

From these data it may be concluded that a moderate exercise plus a 300 ml. external dead space and an expiratory resistance corresponding to the resistance of a severely constricted patient add up to a respiratory load which is well tolerated subjectively and objectively by five of seven subjects. The two subjects who had difficulty when the expiratory resistance was added to the exercise plus the dead space were

TABLE 1
ARTERIAL BLOOD GAS VALUES FOR ANESTHETIZED, PARALYZED VOLUNTEERS DURING VENTILATION BY AN ATTENDANT DOING MODERATE EXERCISE

Subject No.	Control	During Exercise
Arterial Oxygen Saturation (%)		
1	100	100
2	100	100
Arterial Carbon Dioxide Tension (mm. Hg)		
1	32	21
2	28	28
Arterial pH		
1	7.49	7.46
2	7.51	7.52

able to tolerate the added expiratory resistance when the extra dead space was removed. The gas exchange provided a patient even under these extreme conditions would still be adequate.

It is of general interest to the physiology of exercise to observe that respiratory work which is of no moment at rest becomes much less tolerable when a moderate exercise is performed. The dead space of 300 ml. is not noticeable to the resting subject. A resistance of this magnitude is easily tolerated at rest. The exercise itself is not at all fatiguing when there is no added dead space or expiratory resistance. But the combination of exercise and dead space was distinctly noted subjectively and objectively in some subjects and the combination of exercise, dead space and resistance was a real challenge to some subjects. The effects of these handicaps must be additive, a point to be remembered in the design of any respiratory equipment.

Additional studies were carried out in two anesthetized volunteers rendered apneic by intravenous succinylcholine. Following tracheal intubation and attachment of the expired air ventilator these subjects were ventilated by attendants who were simultaneously walking up a one-to-eight grade on a treadmill. Arterial blood samples of the anesthetized volunteers showed oxygen saturations, carbon dioxide tensions and pH values of satisfactory levels. (Table 1.) These values confirm the conclusions from the lung model experiments that the expired air of an exercising attendant provides good gas exchange for an apneic patient.

SUMMARY AND CONCLUSIONS

A technic is described whereby an attendant can ventilate an apneic patient by the use of his own expired air, leaving his hands free for airway management. It is particularly useful during transportation of the patient by ambulance, elevator, hospital cart, etc. After an endotracheal tube is inserted, the attendant has both hands free to aid in transportation. The expired air ventilator consists of a simple mouthpiece and a special three-way valve connected by a flexible tube of about 300 ml. volume. The use of a 300 ml. dead space in the apparatus helps to provide excellent gas exchange. Data obtained from volunteers exercising and ventilating a simulated bronchoconstricted patient with the dead space in circuit indicate that the ventilating gas so produced is adequate for good resuscitation. When the exercise is so severe that the operator is subjectively uncomfortable, relief can be obtained by temporarily avoiding the dead space. He may do this by inspiring through the nose instead of the 300 ml. breathing tube. With the expired air ventilator the apneic surgical patient may be safely transported with a minimum of equipment, especially by skilled personnel.

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DISCUSSION OF PAPERS BY DRS. SCHNEEWIND; AND GREENE, ELAM, BUNNELL AND EVERS

Michael Livingood Mason (Chicago, Ill.): I would like to discuss Dr. Schneewind's paper on the emergency room.

The hospital today is becoming more and more a part of the life of the community. Whereas it was not too long ago that people went to the hospital only on the recommendation of a physician, many now look upon the hospital much as they used to look upon the family doctor. The emergency room of the hospital has, however, too long been considered sort of a necessary nuisance costing money to sustain and seldom paying for itself. It was often staffed on an uncertain basis by one or two nurses whose duty it was to "size up" the emergency, give immediate first aid, and if needed try to locate a physician who would care for the patient. Gradually however, this has changed; the emergency room is now looked upon as an essential public service.

In large cities the emergency service has grown into an integral part of the hospital, especially in those institutions supported entirely, or in part, by public funds. Due to the great increase in farm modernization and to greatly augmented highway traffic, the emergency room in the rural hospital has likewise become more and more important.

A study of emergency rooms made elsewhere has shown that in general they are often not too well staffed and organized for the job they have to do. Equipment and supplies are lacking, personnel are not properly instructed, and too often the emergency room is looked upon as a sort of gratuitous training ground where the inexperienced junior intern learns to put in stitches, or to pump out the stomach of a suspected victim of poisoning. Although situations in the emergency room often

demand the most experienced and careful judgment possible, they are often left to the hands of the youngest and least experienced. Too often the explanation for leaving an emergency to the junior intern as a training for him has been an excuse for avoiding a disagreeable task which came at an inconvenient time.

Several influences are at work, however, to change the whole setup of the emergency services in our hospitals. It is now no longer looked upon as undignified to attend to an emergency case. Somehow the situation as it used to be reminds one of the old attitude of medical men toward the surgeon. The surgeon was a menial who dirtied his hands caring for wounds and ulcers; the medical man worked with his brain and his most difficult manual labor was lifting up the glass urinal for uroscopic examination. I could never see why it should be more dignified to treat a patient who is dying of dropsy and alcoholic cirrhosis than to mend a fractured femur.

Dr. Schneewind has outlined a very excellent emergency room setup combining all the desiderata. First and foremost, it gives the patient the best of service which a large modern hospital and medical school can offer. Into the emergency room come patients with problems having to do with every field of medical science—trauma and poisoning, threatened and accomplished abortion, foreign bodies and lye swallowed by infants, heat stroke, heart attacks and apoplexy, unexplained sudden fever, delirium, mayhem and murder, drowning and asphyxiation. What a diet to serve to the intern and resident with adequate help and instruction so that they may digest it.

The M.E.N.D. program has added impetus to the building up of emergency facilities, particularly with reference to possible need in case of grave national emergencies. However, this training in fundamentals of casualty care works to the good of both the trainee and his patient. The emergency room, which will be the receiving room for casualties, is a most valuable training ground and, as Dr. Schneewind has shown, should be incorporated in the M.E.N.D. program.

The emphasis put on diagnostic problems in the case of multiple injuries is excellent. These are cases which tax the most experienced surgeon, not only in arriving at a diagnosis but also in determining the order in which therapeutic procedures should be performed. Emphasis is placed on careful observation and physical examination without too much reliance upon laboratory studies. When laboratory studies are indicated, the surgeon requests only those that will be of immediate assistance to him. There is no time and usually no need to order the whole galaxy of tests which are so tempting and impressive. This training in securing a history, in making accurate observations and examinations, and requesting only pertinent laboratory data is invaluable to the student.

The provision of a few beds where patients may be kept overnight for observation is likewise a wise one. How many of us have been in the habit of admitting patients to an already crowded hospital simply because we thought they needed a few hours' observation and we did not dare send them out on their own. Many tragedies will be averted by this provision of a few beds.

Last but not least, one can mention the facilities made available for the convenience of those people bringing in the emergency patient. Often they are policemen, who are busy and have their own reports to make, and who thus appreciate consideration.

Dr. Schneewind has said nothing about the records kept but I am sure they are most adequate. They may and often do play an important part in the future history of the case, not only from a legal standpoint but also in determining the continuing progress of the patient's condition.

James Mithoefer (Cooperstown, N. Y.): I would like to ask Dr. Greene if he would be good enough to show us the items he carries in his pocket for emergency use if he finds someone apneic in an elevator, and also to ask him whether these are distributed around the Buffalo General Hospital at strategic points on wards for emergency use.

Thomas Bartlett Quigley (Boston, Mass.): Dr. Greene, is it essential to use an intratracheal tube or is the old-fashioned rubber or plastic airway satisfactory?

Warren H. Cole (Chicago, Ill.): I suppose we will have to agree there are many surgeons who do not have sincere interest in trauma, but I do not think there are any in this organization. This lack of interest will be associated with inferior quality of teaching, and that automatically results in an inferior standard of treatment of the injured patient.

Too often the chief of the surgical department is the chief of the emergency service, and he gets down to the emergency room about once a week, and then for about five minutes. This means that the inexperienced personnel assigned to the emergency room have inadequate supervision. There must be a chief, and he must be one who has sincere interest in the work and have the time to go to the emergency room; he should be a young man with enthusiasm for this subject.

Now perhaps the biggest deficiency I see in a good emergency service program is the inability to get the residents in one specialty to see the emergencies of the other specialities.

It is obvious that only one service can be in charge of a patient, and the patient will automatically be admitted to that service. Therefore it can be seen that the other specialists will be seeing the patient only upon call. I believe you would agree that each trainee, regardless of his specialty,

must have some knowledge of the emergency situations in the other specialties. This need is primarily in diagnosis. Detailed knowledge of treatment is not necessary because the patients are going to be treated by the specialist involved, not by the man who first sees the patient.

In my association with emergency work, my biggest disappointment has been the inability to get the resident interested in the emergency problems of the other services. I would like to make a plea that we try to get the residents to see those other emergencies, because without training many mistakes will be made in diagnosis as well as many delayed diagnoses, and often indeed that will result in a fatality.

WILLIAM H. POTTER (Harlan, Ky.): Dr. Schneewind brought out in his presentation a little matter of medical politics about which we should think. It may be philosophical, but in hospitals which have an obligation to teach there is the problem of whom they are going to teach. Shall the hospital be an ivory tower which teaches just the medical student, intern and resident, or does it have an obligation also to the doctor in the community?

We see cropping up from time to time evidences of hostility between non-specialist practitioners and specialist practitioners; between the people in the grass roots and the people in the higher institutions.

I have a feeling that we have an obligation to teach the people no matter who they are, as long as they are doctors, and I noted that Dr. Schneewind had a form letter to send to the family doctor; 5.8 per cent of their patients were referred back to the private physician. I am not bringing up this point to criticize, because in my work this is a persistent problem. The young man in the institution who is learning, who likes to learn about injuries and to sew, has no real incentive to develop or maintain a liaison with the doctor out in the community who is perhaps not connected with the institution, and if he is, finds it inconvenient to come in. I am groping for the incentives and means to develop communication and a teaching relationship with these men.

In reference to the paper by Dr. Greene and his co-workers, this gives us statistical information which might be transferred to the idea of mouth-to-mouth insufflation. Those of us who have run into the problem of respiratory failure recall a number of instances when this type of apparatus has not been available. It is a beautiful apparatus and I can see its worth if a patient has an intratracheal tube in place. In the instances I recall, an intratracheal tube was not used. The patient's face or tongue was pushed back into his pharynx and we had a problem of airway which either was solved by a tracheostomy or was not solved.

When a patient's face is pushed in, although mouth-to-mouth insufflation has aesthetic objections, I think we should not forget about this technic.

I would like to know from Dr. Greene whether this apparatus can be adapted to a tracheostomy.

BERT H. MCBRIDE (Cincinnati, Ohio): One of my friends, who is an anesthetist, recently went to a meeting and learned a trick, so I do not know who should receive the credit for it. The doctor just stated that mouth-to-mouth breathing leaves something to be desired. The trick is to tape two oral pharyngeal airways together. You use a small airway with a medium-sized one. If the patient is an infant, the small end is inserted. Of course, for the adult the large end is inserted. This method is more efficient as well as aesthetic. I have had a chance to use it only once. It seemed to work fairly well until we could obtain a laryngoscope and insert a tube.

JOHN H. SCHNEEWIND (closing): I should like to thank Drs. Mason, Cole and Potter for their remarks. Concerning our records, we have an Emergency Room form which we purposely keep short so that no one can write very much on it. All we want to know is what was found and what was done. The original is part of the chart of the patient admitted; if the patient is not admitted, the original goes to the medical record room and is retained for subsequent reference in case of medicolegal problems.

Dr. Potter's remark about relations with other physicians is well taken and very important. After all, our hospital operates because the taxpayers of the state of Illinois pay the bill, and the Chicago and other physicians are certainly very important in this regard.

Our percentage of patients referred back to their private physicians is influenced by the fact that a very large number of our emergency room patients are those who have no doctor, would not have one if they knew where to get one, and would not pay him even if they had one. This, then, is our problem.

DAVID G. GREENE (closing): I should like to thank my discussers, who seem to have answered one another's questions to a certain degree. To Dr. Mithoefer I would say that in the emergency resuscitation of the apneic patient obviously most of us are not going to have anything available except our hands and our mouths, and these fortunately are all we need. Mouth-to-mouth resuscitation can be done simply by hooking a thumb under the lower jaw or pushing forward at the angles of the mandible and blowing in through either the mouth or nose with your own mouth, with nothing between you and the subject.

Of course if this area has been shut off, you have to perform a tracheotomy.

As far as what I actually carry around in my pocket, one device is a simple oronasal mask which fits in the breast pocket of a suit. It makes this type of resuscitation much more acceptable in someone who has just vomited or who has blood over his

lips. This mask can be used by professional rescuers, policemen, firemen and emergency room attendants. The other device I carry around in my pocket is the S tube referred to by Dr. McBride. I think the credit for this should go to Dr. Peter Safar in Baltimore, who has recently published a description of it.*

Are these devices distributed around the Buffalo General Hospital? They are—in a plastic bag along with instructions. We teach all personnel to revive the patient first and then send for the apparatus. I did not mean to imply, Dr. Quigley, that an endotracheal tube was a necessary part of this technic. The expired air ventilator can be attached to a simple oronasal mask. If you can keep the airway open by some means other than an endotracheal tube, that is fine. However, in many cases the only way you can be sure of a patent airway during transportation is to use a tube.

I think I have answered Dr. Potter's questions in my summary to the other discussers.

* SAFAR, P. and MCMAHON, M. Mouth-to-airway emergency artificial respiration. *J. A. M. A.*, 166: 1459, 1958.

Standards for Surgical Metals

THERMAL ELECTROMOTIVE FORCE AS A PRACTICAL PROPERTY

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In developing standards for surgical metals many techniques must be evaluated before definitive recommendations can be made. My particular phase of the program is to study non-destructive testing techniques for possible application as part of a standards code. In my search for a non-destructive method of characterizing the surgical alloys, I learned that the thermal electromotive force (Temf.) was a relatively constant property that would identify alloys and would vary if they had been annealed, passivated or hardened differently. There may be an honest difference of opinion on the need for similarity in surgical metals and their properties; but until more evidence has been accumulated in studies on both man and animals, the surgeon should continue to avoid possible galvanic corrosion and its sequella, "electrolytic osteitis." By using the thermal electromotive force the surgeon can assure himself, his patient and his lawyers that he has used similar metals with similar properties.

To understand the Temf. it is necessary to know solid state physics, a science too complicated for this presentation. However, a few basic effects will help the reader to understand

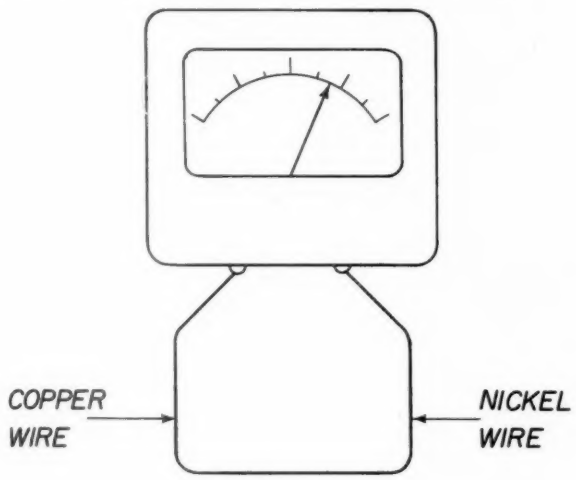

Fig. 1.

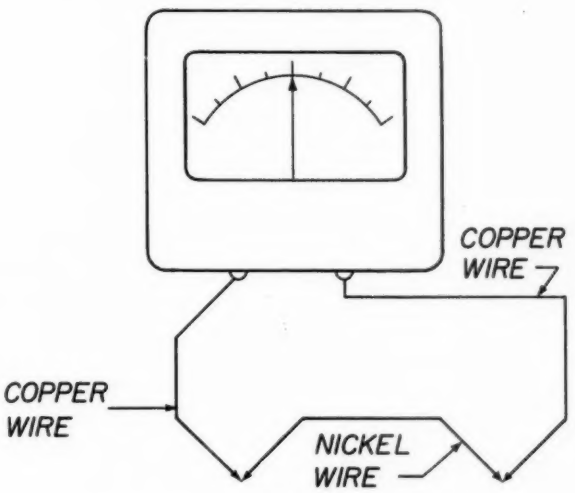

Fig. 2.

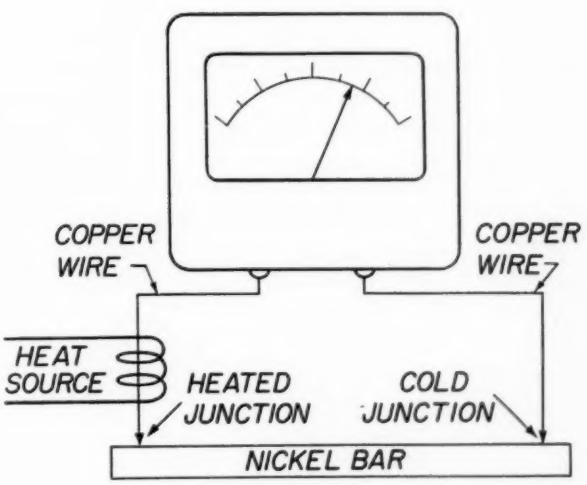

Fig. 3.

FIG. 4.

this property and its measurements. The anatomist, Galvani, was the first to point out that two dissimilar metals will generate a voltage. (Fig. 1.) Later it was shown that the voltage produced at the union was directly proportional to the temperature of the contact point (the conventional thermocouple used by all of us to measure skin temperature, etc.). If two voltmeter leads were attached to a dissimilar metal, two voltages were generated, one at each contact; these balanced each other (Fig. 2) unless one contact was of a different temperature than the other. If these contacts were of constantly different temperatures, the difference in the voltages was the Temf. of the dissimilar metal. (Fig. 3.)

For practical purposes it is possible nondestructively to compare the Temf. of the unknown metal to a surgical standard using an instrument called a Metal Monitor.* This apparatus (Fig. 4) has a heated probe, a cold probe, a meter and a controllable voltage source. The two probes are contacted with the surgical standard; the deviation of the meter is the Temf. of the standard. This is bucked out with the controllable voltage by turning the zero displace knob. (Fig. 4.) The probes are removed and contacted to the unknown surgical device. If the meter remains on or near zero, the unknown has the same Temf. as the standard.

At present we have no surgical standard. That is for the future. However, by using the Metal Monitor it is possible for each surgeon to check the metal components used in any operation to assure the patient that no dissimilar metals are being used. To do this one uses the

* A metal comparator manufactured by The Brush Electronic Division of Clevite, Inc., Cleveland, Ohio.

major component as the "standard," zeros the meter to it, then compares all other components to this standard. Be sure to have the range switch on "B"; the "A" range is too sensitive for present surgical metals.

EXAMPLES

Plates and Screws. Using a four-screw plate as a standard with the Metal Monitor on "B" range, I average testing twelve "similar" screws to find four that have Temf.'s close enough to the plate to be classified as similar metals.

Wire. Surgical stainless steel wire does not have the same alloy composition as plates, screws, intramedullary nails, etc. Multifilament wire suture is composed of two or three dissimilar metals in all the brands tested; one seven-strand wire had four strands of one Temf. and three of another.

COMMENTS

The Temf. does not show metal defects such as internal flaws, grain boundaries, etc. Other non-destructive testing techniques, including x-ray, dye penetrant and possibly ultrasonic or eddy current, will have to be used for these purposes. But the Temf. does characterize the metal or alloy, be it stellite or steel, and will show if the parts have had the same degree of annealing, the same amount of passivation and the same hardening.

I have intentionally avoided giving any definite Temf. values for surgical metals, as no surgical metal standards are available at the present time. I have emphasized the use of comparative Temf.'s because, with the Metal Monitor it is possible to determine if one is using similar metals as a means of protecting the patient against electrolytic osteitis.

SUMMARY

1. The thermal electromotive force (Temf.) is a characteristic physical property of each metal part and will vary with the alloy composition, the degree of annealing, the passivity and the hardness. It may eventually be one of the standards for surgical metals when such standards are established.

2. The Metal Monitor is presented as a non-destructive testing instrument for comparison of implant metals to avoid the surgical use of dissimilar metals.

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Skin Homografts from Postmortem Sources

CLINICAL APPLICATION

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THE use of skin homografts from postmortem sources may be taken as a proved surgical procedure to save lives in cases of severe burn, and the method can be utilized by any surgical service without delay, without special equipment and without waiting for further work in the preservation of the grafts.

The method is open to use to anyone or any hospital that will go to the trouble of instituting the idea, the procurement and the utilization of these grafts which may be life-saving. Any service that does this may be said to have a skin bank in operation.

It is not meant that this is the *only* part of, or the answer to, the care of severe deep burns. All the elements of care are still needed, but postmortem homografts offer a way of closing wounds temporarily without having to resort to multiple live donors with the attendant anesthetics, operations and debilitations. This method makes skin easily obtainable so that the advantage of homografts can be given to more patients.

It seems unnecessary to say that homografts last only three to eight weeks, except in identical twins, and that the patient's own skin will have to be used for permanent healing, function and appearance in extensive losses.

Front page news items are still seen concerning the fact that many persons have volunteered to give their skin for a burned child. It is our belief that taking homografts of skin from live donors is no longer necessary and that in instances of need the homografts may be obtained from postmortem sources. This is possible because of a differential of time between general death and final death of skin, of several hours or even days, during which time the skin grafts can be removed. Such removal does not interfere with the patient, with the relatives or with the funeral procedure, because only partial thickness split grafts are taken from unexposed areas.

Removal of the split skin grafts from the person who has died and covering the wounds of the patient who might otherwise die is a dignified surgical procedure. Human worth and dignity thus may be carried even beyond death, in that the patient who has just died has saved the life of another patient even after his own death. (Figs. 1 and 2.)

At the present time an important element in the use of postmortem homografts is to try to get the public to accept the idea of allowing superficial layers of skin in unexposed areas to be removed after death for such use. Also important is the acceptance of the idea of this surgical procedure by the profession as a whole.

These grafts can save lives by offering "biological dressings" for wounds that otherwise might be fatal; and if large supplies of the postmortem grafts were available, they could be used as dressings on burns of lesser extent and depth.

The legality of obtaining these grafts is of importance and may differ from state to state and country to country. In some states the body of the decedent is the property of the nearest relative regardless of the patient's views or wishes during life, and such a relative should give permission for removal of the skin. There is usually little difficulty in obtaining permission if the responsible relative can have a clear description of the process and perhaps be shown the patient or the child who is so in need. It has been said that this would be difficult in England, but Sweden has taken a step toward

FIG. 1. Extensive deep loss of skin which required prompt removal of necrotic involvement and coverage at the same operative procedure with postmortem skin homografts. Homografts lasted usual length of time, but then patient was able to stand the transference of his own skin for permanent healing.

making all tissues available from deceased persons. A written, signed permission such as for a regular postmortem examination is obtained and these grafts may be permitted even if an entire autopsy is withheld.

There are many details to be worked out, such as the most advantageous times of obtaining, storing and utilizing these homografts from postmortem sources, and naturally one thinks of storage of these grafts. They may simply be stored for three weeks at normal refrigerator temperature +4°c. and still be used. The grafts are folded raw surface to raw surface and kept in covered dry sterile garuze. Slight dampening with saline or other solution and addition of penicillin and nutrients have been carried out however, the grafts should not be kept soaking in anything. Other methods of cold storage are being studied, and non-viable freeze-dry preparations may be resoftened with saline solution and used with almost as much advantage as viable grafts. The closer to the time of removal from the donor the graft is used, the longer it may last. However, there is evidence that retention of the skin for a few days on a refrigerated body may lend some days to the persistence of the grafts when used.

FIG. 2. Permanent solid healing allowing for complete functional return and satisfactory appearance.

In the literature suggestions range from bizarre to unnecessary experimentation on patients with small lesions when autografts could have been used and healing completed. There is no reason to subject patients or volunteers to experimentation for any data when small laboratory animals can be used, including the transplantation of human skin to the animals for observation of its properties. There is no reason to waste homografts when the patient's own skin can be used and permanent healing obtained.

SURVIVAL OF HOMOGRAFTS

Takes of Grafts, Permanence of Grafts, Duration of Survival. Almost any viable skin will "take" as a homograft without reference to blood, skin groups or relationship. Even the skin of animals may appear to do so, and also will the skin of human beings to animals. However, as noted, up to this point homografts do not persist permanently and have a relatively short duration of viability except from identical twins. This finding (1932) of the permanence of survival of homografts from identical twins has been the basis of the transplantation of the kidney from one identical twin to the other.

It is apparent that the designation of "take" does not mean permanent survival.

Permanent viable survival of tissue from others or deceased persons is a goal of such great potential as to stimulate and require extensive continued investigation. Whether ir may ever be solved or not is about as questionable as to whether other "first causes" may be made clear.

Certainly all possible investigative work should be done, but at present there is little clinical application of elements that seem to permit of at least increased duration of viability of homografts. Those elements include agammaglobulinemia, sublethal radiation dosage, pregnancy, desensitization of recipient, use of closest possible kin and trying to acclimate the recipient at young age (or prenatal) to a possible donor later in life.

SUMMARY

For this summary several previous publications have been drawn from and the clinical conclusion is included in the first paragraph.

The Burnt Hand

CLIFFORD L. KIEHN, M.D. AND JOHN D. DES PREZ, M.D., *Cleveland, Ohio*

From the Department of Surgery, School of Medicine, Western Reserve University, and the Department of Surgery, St. Luke's Hospital, Cleveland, Ohio.

MANY permanent hand disabilities occurred in World War II which would be completely preventable in peace time if certain principles were followed. Numerous uncontrollable factors in wartime prevented the early institution of proper treatment, such as failure of pilots to wear adequate hand protection as compared to tank men, and delay in transportation, to name a few. (Fig. 1.)

It is now possible with the facilities of the Aero Medical Evacuation Service of the Air Force to transport patients with extensive burns to treatment centers several thousand miles away. This was not accomplished in World War II and thereby many valuable days were lost before definitive treatment could be started.

Time is a most important factor in the treatment of the burnt hand. Immediately upon receiving thermal injury there is the production of edema, the actuator of a transudate, which in turn produces a serofibrinous deposit on all deep structures. This is the enemy of normal function which results eventually in ankylosis of the joints and inhibits the normal sliding of tendons.

Edema and later adhesions fill the deep spaces of Kanavel around the extensor tendons and these gliding structures then become attached to both the superficial and deep tissues. This produces the reverse arching of the palm and hyperextension of the metacarpophalangeal joints. (Fig. 2.)

Edema is the product of trauma and if present must be prevented or reduced as early as possible. This can be accomplished or diminished with early, adequate pressure dressings or immediate excision and skin graft [1].

No matter what the depth of the burn, the primary treatment is to control pain, wash the hand with sterile saline and remove all the shreds of devitalized tissue as well as open all blisters under conditions as sterile as possible [2].

A water-soluble ointment containing penicillin fulfills the need of an emollient that does not do further damage to the hand and acts as a bacteriostatic agent when used directly on the wound.

Dressings applied to the hand to prevent edema must not be haphazard nor austere if the decision is made not to excise the devitalized tissue and graft immediately. Too frequently the dressings are delegated to the inexperienced junior member of the staff and there is failure to achieve the goal of adequate pressure and correct immobilization in the position of function.

The first dressing need not be removed for one week if circulation of the fingers is normal and no infection develops.

By the end of the second week the partial thickness loss will be healed and the devitalized tissue will begin to separate. The dressings should be changed daily to remove the slough

FIG. 1. Unepithelized deformities of pilot's hands resulting from failure to graft early because of 50 per cent body burns and complications.

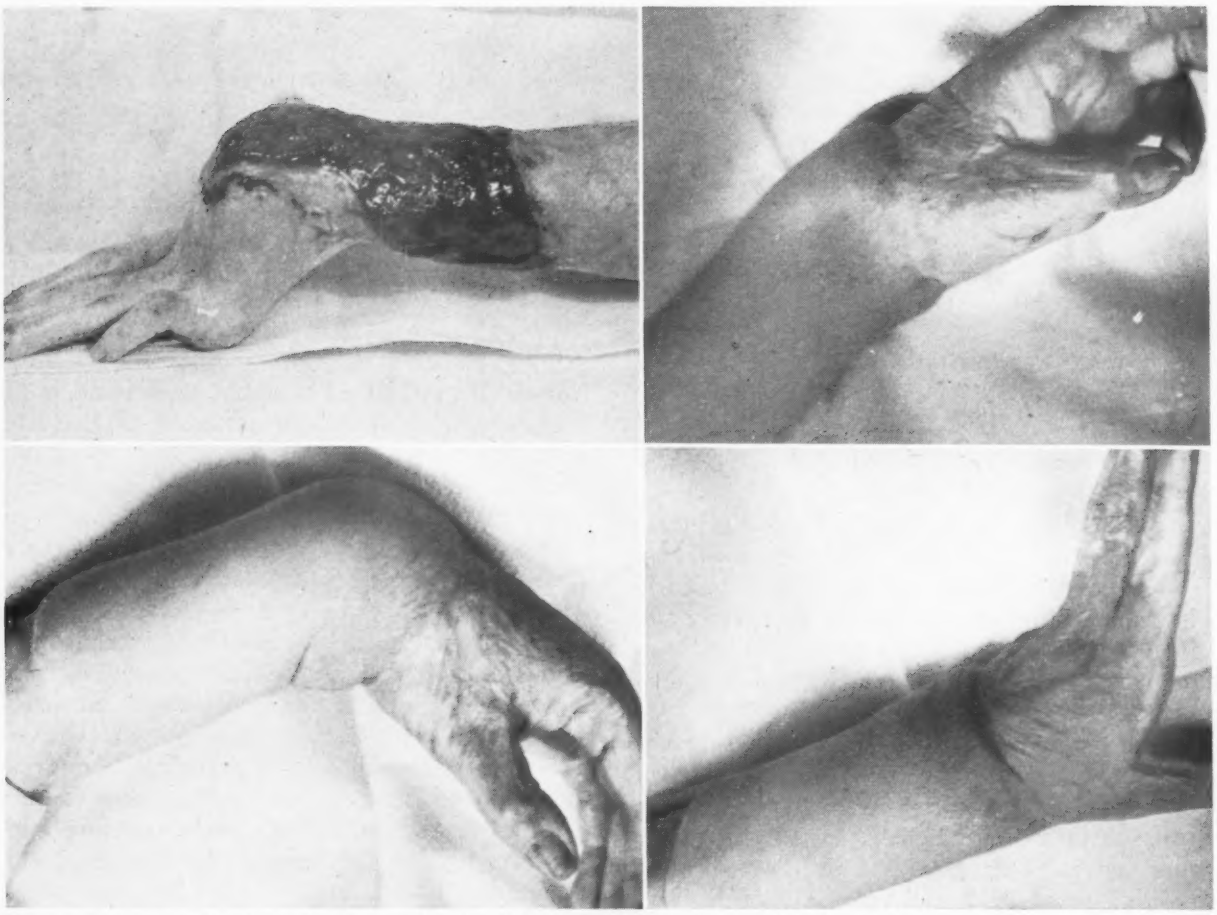

FIG. 2. Patient D. H. Ungrafted burnt hand and forearm show typical deformity of reverse arching of the palm and flexion contracture of the wrist and correction with 360 degree abdominal pedicle flap and split graft to dorsum. Capsulotomy was performed upon all metacarpophalangeal joints.

and prevent the accumulation of exudate. The wound should be ready to graft two weeks after burning if this regimen has been followed faithfully. Grafting at this time will insure that an adequate envelope of skin will be supplied for normal function [3].

A split skin graft, properly applied, will "take" on young granulations if they are flat, smooth and shiny, with an absence of gross exudate. The graft will not be successful if placed on an edematous, infected granulating surface. (Fig. 3.) It must be emphasized that split grafts should be placed only on very young granulation tissue or they should be entirely removed if old. As granulations age, a layer of fibrous tissue is laid down which eventually splints the hand in deformity, constricting circulation and function as time goes on without a graft.

The failure of a graft to take may be due to two factors, i.e., hematoma and infection. The latter can be controlled by proper preparation of the wound preoperatively and the use of antibiotics postoperatively. Hematoma can be held to a minimum by the use of a tourniquet while dissecting and preparing the wound for the graft, letting the pressure down to tie off all bleeders and then putting it up again while the graft is being sutured in place. The pressure should be kept up until the massive pressure dressing is applied. (Fig. 4.)

Postoperatively the graft should be inspected in twenty-four to forty-eight hours for hematoma. If hematoma is present, it is evacuated and abscesses are opened and drained. Pressure is reapplied for several days and motion is started within two weeks after the operation.

Unfortunately, all burnt hands are not seen immediately after injury. These cases may present many difficult problems in restoration of function because of the constricting fibrous tissue, chronic inflammation and infection.

FIG. 3. Edema of granulations from inadequate dressings with joint fixation. Graft should not be applied to this surface.

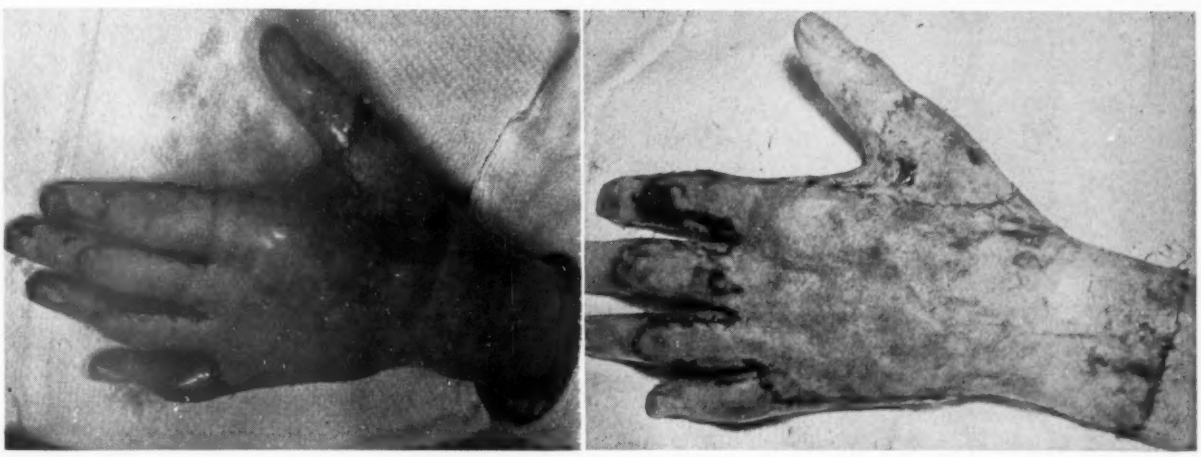

FIG. 4. *Left*, one drum of skin is an inadequate envelope to cover an adult dorsal hand. *Right*, loss of part of graft from hematoma; first dressing.

In preparing the wounds for grafting the usual mistake is the placing of the graft on a poor bed. All old granulations and all fibrous tissue must be completely excised down to the tendon sheath; this procedure insures the insertion of a normal area of skin for an adequate envelope.

If the joints are ankylosed in the position of malfunction, all fibrous bands must be removed; and if the joint surfaces are impaired, bony ankylosis should be performed in the position of function after the graft is well healed.

There are a selected number of cases in which grafting may be carried out immediately after burning, or at least within a few days before the slough has begun to separate. This technique has several pitfalls, the most important being determination of the extent and depth of devitalized tissue to be excised. This may be judged by several methods, but none of them are accurate and the inexperienced surgeon may needlessly excise vital tissue or tissue that may recover after the initial trauma.

The absence of pain as demonstrated by pinprick is a very coarse method of discrimination between live and dead tissue. Another method is the administration of radioactive isotopes to determine the variance of uptake as a sign of viability. This method probably has the greatest potentiality but is not entirely accurate and requires equipment not readily available [*4*].

After the devitalized area is determined and excised, hemostasis is obtained and a split or pedicle graft is applied as indicated heretofore.

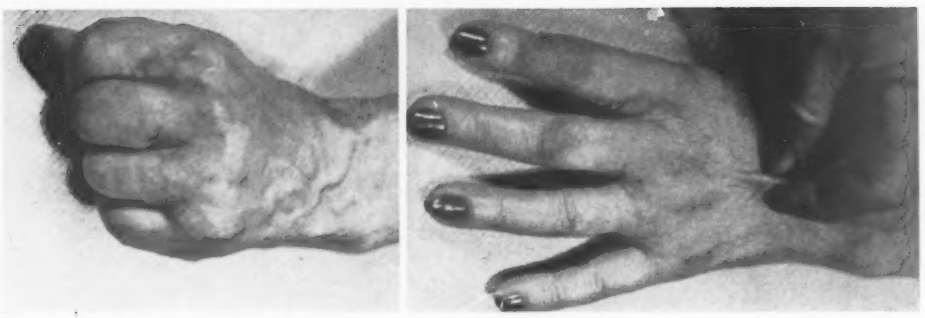

FIG. 5. Patient V. L. *Left*, dorsal coverage with 95 per cent return of prehensile capacity after capsulotomy and Z-plasty to webs. *Right*, full extension of all joints with soft, pliable, adequate envelope after two years.

FIG. 6. Patient D. B. *Left*, full-thickness burn which was allowed to heal without graft. *Right*, complete take of graft which will require deepening of web spaces; first dressing.

The following cases represent some of the problems encountered in restoration of the burnt hand.

CASE REPORTS

Patient D. H. received burns of the hands and face when a gasoline station blew up while he was having the gas tank of his automobile filled. The only treatment of the burnt areas was a daily change of dressings, which resulted in a completely useless hand because of severe reverse arching of the palm, flexion fixation of the wrist and hyperextension of the metacarpophalangeal joints and thumb. A 360 degree abdominal pedicle flap was placed on the forearm and wrist to cover both extensor and flexor tendons and muscles after all fibrous tissue was removed. The dorsal surface of the hand was then covered with a thick split graft. (Fig. 2.)

Mrs. V. L. received a full-thickness burn of the dorsum of the hand and forearm. This was not grafted for several weeks after the injury and demonstrated the deposition of deep fibrosis preventing the normal function of joints. It also shows that a dorsal thick-split skin graft after considerable time will become resilient, soft and pliable, and will allow full flexion because of a combination of capsulotomy and an adequate envelope of skin. (Fig. 5.)

Patient D. B., an eighteen month old infant, received burns of the face and hands. No grafts were applied to the hands because of delay in treatment to see if the injury was a full-thickness burn. The resultant deformity required complete excision of the dorsal scar down to the deep fascia covering the extensor tendons. The graft healed completely with returning function without capsulotomy. The web spaces will be deepened at a later time. (Fig. 6.)

Patient R. N. received full-thickness burns of the flexor surfaces of the little and ring fingers of the left hand. No graft was applied and contracture resulted. Full-thickness free grafts were sutured into the defect after complete excision of the scar. There was full return of function. (Fig. 7.)

Patient P. K. received a crush-burn injury to the dorsum of the hand at the age of four. Six weeks later an abdominal pedicle graft was placed on the defect of the hand and fingers. This type of

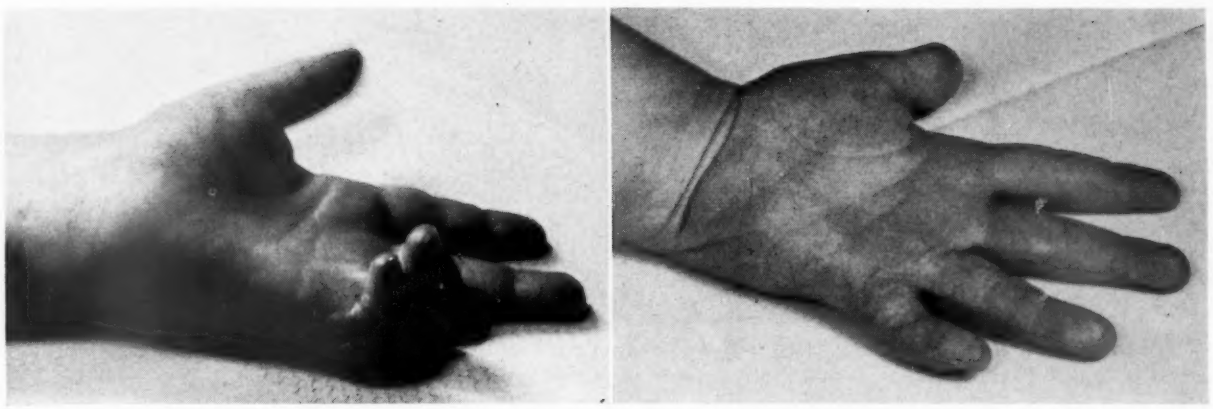

FIG. 7. Patient R. N. *Left*, flexion contracture of little and ring fingers from deep burn which was allowed to heal without graft. *Right*, full extension after complete excision and covering with full-thickness grafts.

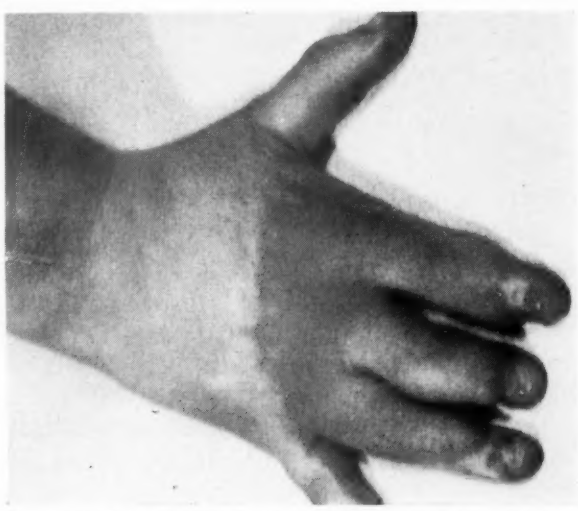

FIG. 8. Patient P. K. Crush-burn mangle injury. Joints and tendons were covered with a pedicle graft six weeks later.

FIG. 9. Patient C. D. Hand grafted four hours after burning. The little finger was amputated later because of the deep burn and onset of gangrene.

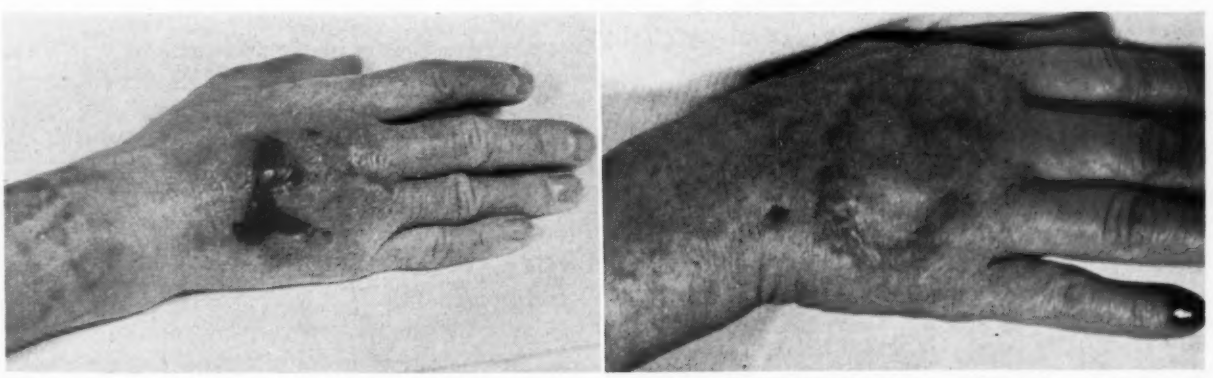

FIG. 10. Patient E. H. *Left*, small dorsal burn which was excised and grafted on the sixth postburn day. *Right*, complete take of graft after excision with full return of function. The patient was hospitalized for one week.

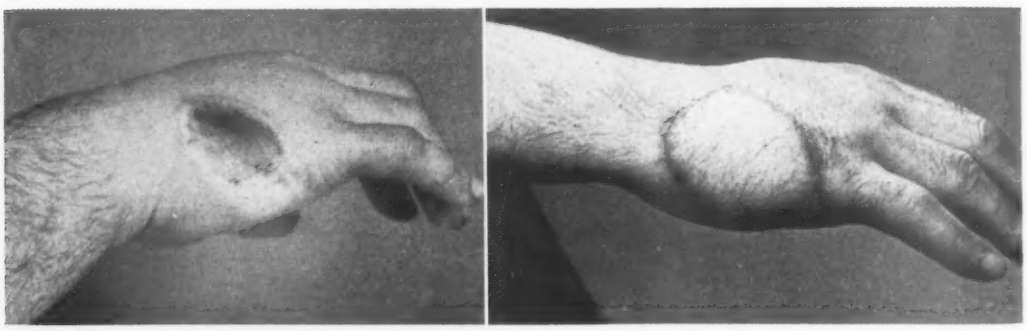

FIG. 11. Patient G. D. *Left*, deep well demarcated burn immediately excised. *Right*, pedicle graft applied to immediately excised burn because of exposure of bone and tendon.

graft was chosen because of exposed joints and tendons. The graft was later thinned and the middle metacarpophalangeal joint of the index finger was fused in the rest position. (Fig. 8.)

Mrs. C. D. was preparing supper when she had an epileptic spasm and fell onto the lighted stove. Her right hand was in contact with the flame for an undetermined length of time. The burnt area was well demarcated but the extent of depth could not be completely determined. The visible devitalized tissue was excised four hours after burning and a split graft was applied. The little finger was eventually amputated because it became gangrenous. This demonstrates the inability to judge the depth of a burn completely at the time of grafting. (Fig. 9.)

Mrs. E. H. burned her hand in a mangle and was seen six days later. The area was small although well demarcated, and was excised and immediately grafted. There was a 100 per cent take and no further revision was required, saving considerable hospitalization and disuse of the hand. There was an early return of function. (Fig. 10.)

Mrs. G. D. sustained a well demarcated burn of the medial aspect of the hand. On excision the burn was found to be very deep with exposure of tendon and bone. This defect was covered by an immediate pedicle graft from the abdomen. Three weeks later the pedicle was severed and healing was complete with no further revisions.* (Fig. 11.)

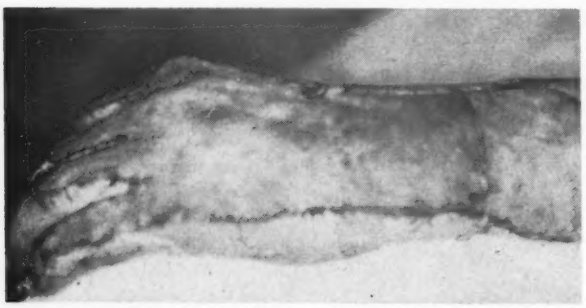

FIG. 12. Patient A. B. Nearly complete dorsal burn covered with a split graft four hours after burning, with an excellent take and return to function three weeks later.

Patient A. B. received a full-thickness burn of the dorsum of the hand when it was pinned under an overturned tractor. Four hours later the devitalized tissue was excised and covered with a split skin graft. He returned to full duty three weeks later. (Fig. 12.)

SUMMARY

Deformities from deep burns of the hand result from the sequence of edema, infection, suppuration and fibrosis. This irreversible cycle must be broken by the institution of early proper treatment, namely, the application of adequate skin coverage.

The prevention of the fixed burnt hand can best be accomplished by placing the hand immediately in a position of function, elevation and occlusive voluminous pressure dressing. This will prevent the formation of massive edema.

Infection cannot occur if the pellicle of crust and devitalized tissue is kept intact until replaced with a graft. If the hand is seen late and the slough has begun to separate with the formation of granulation tissue, this process should be encouraged and assisted to acquire rapidly an ideal base to receive the split graft. It must be remembered that if this process is prolonged, a layer of fibrosis is laid down under the granulation tissue. The older the burn, the more dissection must be performed for the graft to lie on a bed which will supply early subsistence. This bed or recipient site is on the fascia covering the extensor tendons. This a!so holds true if a decision is made to excise and graft immediately.

* Patient was operated upon by Dr. Robert Waltz.

It cannot be emphasized too much that the hand is covered by a great deal more skin than is generally supposed. A common error in the application of a split skin graft is the belief that one full drum of skin will cover the dorsum of an adult hand. To cover the entire area of the dorsum and fingers will require nearly two drums.

Two weeks after the graft has been applied motion should be started, after which secondary surgical procedures may need to be carried out such as Z-plasties to the interdigital webs and capsulotomies to improve function.

We advocate earlier grafting of the burnt hand than has been done in the past. If there are no complications, we believe that the best functional result can be obtained with excision and graft in one stage to prevent the invasion of bacteria and fibrosis. This will also diminish the patient's hospital stay and decrease morbidity as well as eliminate the necessity of joint surgery.

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DISCUSSION OF PAPERS BY DRS. BLUNT; BROWN, FRYER AND ZAYDON; AND KIEHN AND DES PREZ

H. Hoyle Campbell (Toronto, Can.): I wish to congratulate the speakers on their very excellent papers. My main interest is in the paper on the burnt hand and I would like to congratulate Drs. Kiehn and Des Prez on their excellent presentation. I would agree heartily that time is important in the management of the burnt hand. Very often, even with cases under our control, we are sometimes caught with the severely burned patient with extensive upper facial burns requiring our attention first, and are thus unable to graft the hands as soon as we would like.

In such patients who are not treated for three to four weeks there is a gradual development, as Drs. Kiehn and Des Prez have shown, of an extension deformity of the metacarpophalangeal joints of the hands. As more and more scar is laid down in the bed of the granulation tissue, if we do not remove this scar before we graft, we are left with an extension deformity of these joints unless a second operation is performed to overcome such contracture. To avoid this possibility I believe that a tourniquet may be applied to the limb at the time of operation and all the granulation tissue and scar be removed down to the healthy bed. In so doing we overcome much of the scarring in the bed, and in grafting I believe that we should extend the dissection back to normal skin.

Now when a graft is applied to an ideal bed and extra sheets of skin are used to complete the coverage, I believe the lines should be broken in such a way that the eventual suture line will appear as a Z.

With the line so broken, when the metacarpophalangeal joints are flexed and the graft is mobile, the Z limbs open outward and prevent contracture along these suture lines. Similarly, on the flexor surface the graft is carried well around to the axis of movement of the various joints so that these lines are broken along the sides of the digit.

I think that with such a technique the final and most effective result may be gained quickly and thus save secondary operation.

William L. White (Pittsburgh, Pa.): I, too, would like to express my appreciation of Drs. Kiehn and Des Prez's paper, for their results speak of their great experience in the management of these very difficult problems. Fortunately, most burns of the hands are relatively superficial and will heal spontaneously. Those that are somewhat deeper can be corrected by means of early excision or later débridement and be secondarily grafted with split-thickness skin. Perhaps the greatest difficulties in the management of burns of the hand are those encountered with deep burns that destroy tendons and the dorsal aponeuroses of the fingers.

I would like to ask Dr. Kiehn whether or not he would advise early complete excision of all damaged tissue, including tendon and dorsal aponeurosis in the deeper burns, or whether he would advocate natural separation of necrotic tissue in an attempt to salvage as much of the functioning structures as possible. We have found that with this slower method it is often possible to preserve some extensor tendon action even though these structures have suffered thermal injury.

Truman G. Blocker (Galveston, Texas): Regarding the presentation by Drs. Brown, Fryer and Zaydon, I believe we should all remember that homografts are useful chiefly to save a life. We have carried out some experiments in the last three or four years with Dr. Eade, who is now in Seattle, Washington, in which the bacterial counts of granulation tissues have been taken before application of autografts and homografts (fresh or lyophilized), and then taken at various intervals of time after by peeling back the grafts. We have been amazed to find that although the bacterial count of granulation tissue briefly washed and cleansed prior to grafting is still very high, after-

ward there will be a remarkable reduction in the bacterial count. By twenty-four hours usually no growth will be obtained. Granulation tissue probably has the ability to sterilize itself as an inherent quality if given the proper environment.

JAMES MITHOEFER (Cooperstown, N. Y.): There were a number of things I thought were of considerable interest in these papers which I did enjoy.

I would like to ask Dr. Fryer how long he has stored the cadaver homografts. We know bone marrow can be stored at these low temperatures in glycerol for periods up to six months and remain viable. We have not been doing it any longer than six months, so we do not know how long they will remain viable.

J. W. BLUNT, JR. (closing): The property of thermal electromotive force was obviously confused and programmed with the results of thermal energy: The energy causes burns; the property will, I hope, prevent surgeons from getting "burned."

Some day metal and metallurgical standards will be established for the surgical and orthopedic metals; there are none at present. Until that time the thermal electromotive force, used as a comparative measurement, will help to prevent mixing dissimilar metals in patients.

MINOT P. FRYER (closing): To answer the question of how long homografts can be stored, we have stored them for two and a half years. Those have been lyophilized and also stored at −80°C. That does not mean, of course, that it is viable skin at that time, but these homografts can be used for coverage.

There is no question but what fresh homografts give more satisfactory coverage than homografts stored under any means.

There is one other thing I would like to mention in closing, and that is that we fully understand the importance of fluid in the early treatment of burns, but still the over-all survival of burns has not improved very much in the last 100 years. The only way that we can expect survival to be increased in deep, extensive loss of skin is by the early replacement of skin. Homografts provide that means and postmortem homografts provide an unlimited source.

CLIFFORD L. KIEHN (closing): In answer to Dr. White, I do believe that the very deep injuries to the hand such as a burn-mangle injury should not be débrided completely because it is impossible to demarcate in your own mind that which is vital or devitalized. We should leave that to the body because it is its own best separator.

It has been pointed out by Blunt and Dingman that radioactive isotopes have been used to distinguish between vital and devitalized tissue by the ability of the vital tissue to take up the isotopes. This, however, requires much more research and experience but may eventually be the answer to this problem.

New Concepts in the Treatment of Surgical Wounds

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DURING the past ten years our studies on the treatment of the burned patient have involved re-evaluation of the previous existing regimens for the care of the surgical wound. The burn wound, viewed in its entirety, actually represents a collection of many types of surgical lesions. To further our evaluation of new pharmaceutical agents, techniques and dressing materials in the treatment of the burned patient, we first studied their effects in the numerous isolated wounds found in a surgical center [*1–4*]. These studies were carried out on the wards of St. Vincent's Hospital.

PROTEOLYTIC ENZYMES AND ANTIBIOTICS

The employment of antibiotics in the treatment of the systemic efiects of infection arising from surface wounds reduced morbidity and mortality to a dramatic degree. However, parenteral antibiotic therapy was limited in its effects on the wound itself. It was capable of reducing the inflammatory reaction about the wound and in most instances of controlling its regional spread, but only epithelization controlled the local contaminating bacteria. The application of antibiotics to the wound surface had few advantages and many disadvantages. The most important of the latter were the developement of bacterial resistance, hypersensitivity manifestations and delayed wound healing. Local antibiotic therapy often resulted in havoc when the organisms became resistant to the antibiotic, and subsequent reinvasion resulted in septicemia. In recent years the careless reliance on antibiotic control of the systemic manifestations, while pathogens freely propagated in the wound, has in a number of instances fostered pathogen resistance and, through cross infection and contamination of medical personnel, resulted in a dramatic increase in deaths from sepsis among hospitalized patients. A possible control of the aforementioned developments became apparent in our study of proteolytic enzymes to lyse necrotic tissues.

In an attempt to débride the necrotic debris of the burn wound, a number of proteolytic enzymes were studied in stasis and decubitus ulcers, surgical wound infections, and fistulous and sinus tracts. In all instances the patients were protected with parenteral antibiotics. As the necrotic tissue elements were lysed [*5*], purulent exudates were rapidly converted to transudates. Once the wound was rid of its necrotic debris, epithelial elements from the periphery of the wound began to migrate, and if the wound was sizeable skin grafts were readily accepted. To date, the most effective enzymes for fibrinolysis have been streptokinase, fibrinuclease and trypsin [*6–8*]. This group of enzymes, however, has no effect on denatured collagen. This substrate seen in devitalized skin and fascia is rapidly dissolved by the vegetable enzyme derived from ficin* [*4*].

As usual, this sequence of events is not uniform and has a number of pitfalls for the unwary.

The employment of an enzyme under a sealed dressing, coupled with the patient's body temperature and the presence of the breakdown byproducts of the enzyme on the necrotic tissues, has allowed for rapid bacterial proliferation in the wound. To some extent, frequent changes of dressings and reapplication of the enzyme control this bacterial incubator, but in extensive wounds this is impractical. The natural

* Debricin, supplied by Johnson & Johnson, New Brunswick, New Jersey.

TABLE 1
REQUIRED TREATMENT TIME FOR SKIN GRAFTING OR HEALING

Types of Infected Wounds	Saline Soaks	Proteolytic Enzyme	Enzyme Plus Antibiotic
Stasis ulcers:			
With exudate alone	2–4 days	24 hr.	6–24 hr.
With fascial involvement	2–4 wk.	4–10 days	4–10 days
Decubitus ulcers:			
Roofed	4–6 wk.	5–15 days	5–10 days
Unroofed mechanically	4 wk.	2–10 days	2–6 days
Miscellaneous:			
Operative wounds	3–5 days	24–48 hr.	12–36 hr.
Abscesses (incised)	3–6 days	24–48 hr.	12–24 hr.
Burn wounds:			
Superficial 2nd degree	2–4 days	24 hr.	24 hr.
Deep 2nd and 3rd degree	2–3 wk.	4–9 days	4–6 days

step was to combine the enzyme with an appropriate antibacterial agent. This has been done, but the compatability of the agents must be carefully evaluated prior to use, as they may inactivate one another.

In our series of over 500 wounds we found this technique very effective, provided certain criteria were met (Table 1 and Figs. 1 and 2):

1. The wound eschar must be a substrate suitable to the enzyme so that lysis of the wound culture media proceeds rapidly.

2. Dressings must be changed frequently, i.e., every twelve to twenty-four hours, so that inhibitory by-products to enzyme activity do not accumulate.

3. The antibiotic selected must be used in bactericidal levels and be appropriate for the predominant organisms in the wound.

4. The antibiotic must be compatible with the enzyme.

5. The wound surface must be epithelized as soon as the necrotic tissues are removed.

Failure will almost invariably occur if any of the aforementioned are neglected. The most frequent cause of failure, resulting in a chronic ulcerated wound, is delay in utilizing skin grafts. The advent of the electric dermatome has made this delay a mark of negligence. A second prominent cause of failure has been procrastination in the use of an enzymatic agent on an unsuitable eschar substrate. If the eschar is not lysed in ninety-six hours, surgical intervention is indicated. The ideal enzyme that will selectively remove all the necrotic substrates of the wound in a matter of hours is yet to be developed, and until that agent is realized enzymatic débridement will only be an ancillary tool to surgical excision.

ANTI-INFLAMMATORY DRUGS

The acceptance of inflammation as a beneficial host reaction has been challenged in recent years [*9,10*]. The various factors involved in the inflammatory reactions are not completely understood, but the increase of capillary permeability, fibrin-plugged venules and lymphatics with resultant edema, and the constantly increasing scar tissue base have seemed responsible for the inability of parenteral antibiotics to reach the wound crevices in bactericidal levels. These factors have also been held responsible for the constant devitalization of the surface tissue elements, thus providing media for further propagation of bacteria. In recent years certain agents such as streptokinase, trypsin, prednisolone and phenylbutazone have demonstrated a capacity for inhibiting or reversing the usual inflammatory reaction to tissue injury [*11–14*].

Our experience in treating patients with infected lesions such as ulcerations, surgical wounds, cellulitis and abscess formation with these agents, combined with the appropriate antibiotic, has been very dramatic. They are effective in hastening the decrease and swelling about the wound, thus allowing early definitive surgical intervention or rapid healing.

Recently a new agent derived from phenylbutazone (known as G-27202*) has been used in the control of postoperative incisional wound pain [*15*]. Patients have been given an oral dose of 300 mg. twelve to sixteen hours prior to surgery and a maintenance dose of 100 mg. every eight hours for two days after fully recovering from the anesthesia. In our fifteen patients undergoing a variety of surgical procedures, such as hemorrhoidectomy, herniorrhaphy, exploratory laparotomy and thoracotomy, there has been no instance of postoperative pain and the usual narcotic agents were not used.

These anti-inflammatory agents have some very definite toxic characteristics but are comparatively safe for short course therapy. In all instances when the inflammatory response is due to or accompanied by bacterial activity, the anti-inflammatory agent must be accompanied by an appropriate antibiotic and, if

* Provided by Geigy Pharmaceuticals, Ardsley, New York.

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FIG. 1. Patient with chronic varicose ulcer that has been treated with multiple daily potassium permanganate soaks for three weeks.

FIG. 2. Same patient. Appearance of ulcer after five applications of debricin and chloramphenicol.

indicated, surgical intervention to establish drainage.

WOUND DRESSING TECHNIQUES

To further the concept of gentle atraumatic® wound handling, it became imperative that a non-adherent wound contact dressing be used. The desired dressing must be non-macerating, non-toxic and non-adherent on a variety of wound surfaces ranging from skin graft donor sites to infected granulation tissue wounds. In our program the most useful dressing found has been a rayon mesh impregnated with a light mineral oil* [17]. This dressing may be atraumatically removed from a deep donor site wound within seven days and a second skin graft obtained. (Figs. 3 and 4.) When used over a granulating wound, there is no ingress

* Adaptic,® furnished by Johnson & Johnson, New Brunswick, New Jersey.

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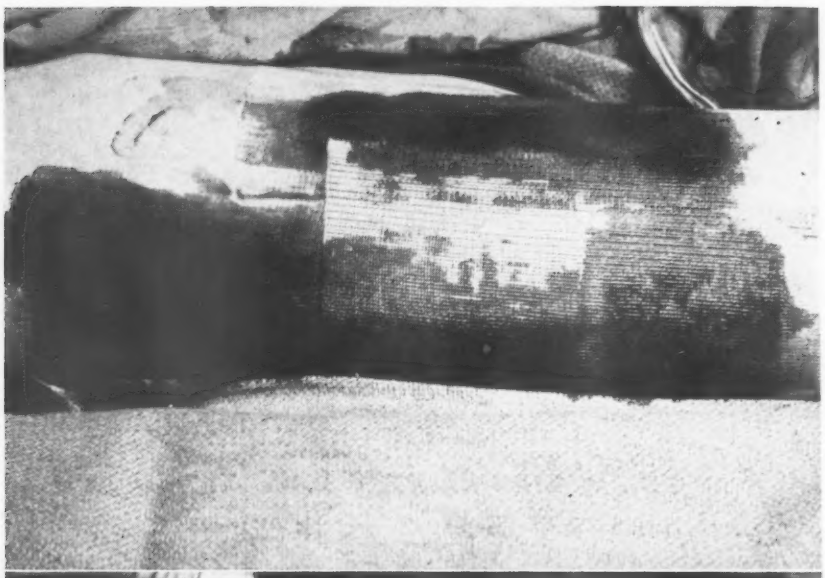

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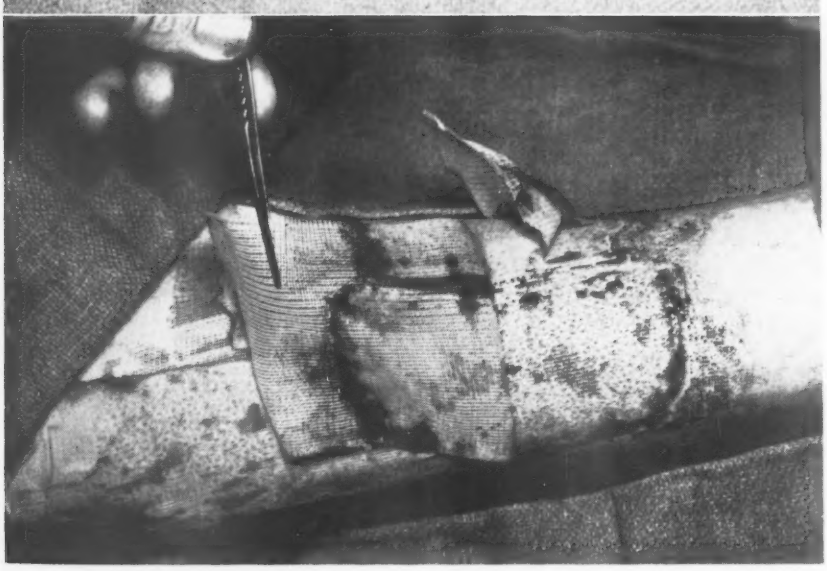

FIG. 3. Freshly taken skin graft dressed with rayon-impregnated dressing. Skin graft is .017 inch in depth.

FIG. 4. Removal of rayon-impregnated dressing five days following surgery.

of tissue or clotting of fibrin in the interstices of the mesh, thus preventing puddling or maceration and at the same time allowing for atraumatic removal of the dressing.

One of the most difficult wounds to prepare for skin grafting is the large infected granulation tissue wound. This edematous, inflamed tissue is incapable of supporting skin grafts. We have found these wounds may be efficiently prepared as follows: excision of the excess tissue to the healthy scar base; the application of a firm absorbent dressing over a non-adherent contact dressing; and the maintenance of wound drainage by irrigating the dressing with a limited amount of a fibrinolytic enzyme combined with an appropriate antibiotic. The dressing should be just moist and never soggy. After seventy-two to ninety-six hours the wound will be clean and receptive of skin grafts. After the grafting procedure we have resorted to irrigations with normal saline until the first dressing is applied four to five days later.

CONCLUSIONS

There have been a number of significant developments in the armamentarium of the surgeon for the improved handling of surgical wounds. The primary requisites of strict aseptic

technique, hemostasis and gentle handling of tissues have not been changed but only further emphasized. The addition of fibrinolytic and proteolytic enzymes, antibiotics, anti-inflammatory agents and the non-adherent dressing are ancillary devices to promote further our efficiency in wound management for rapid, uncomplicated healing.

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The Place of the Cross-Leg Flap in Traumatic Surgery

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WOUNDS with loss of soft tissue upon the foot and leg present many problems. Because of relatively poor vascular circulation to these peripheral parts, healing may be delayed with cicatrization. Scarring of this area may produce unresilient cover to mobile parts such as the ankle or Achilles tendon, and exposes such a vulnerable area to a myriad of low lying objects, all of which seem to conspire to seek out and to injure these wounds. Too, with underlying bone so near the cutaneous surface, osteomyelitis or septic arthritis may result; if the cutaneous loss is coupled with bony fracture, non-union may ensue.

The Use of Free Grafts of Skin. Wounds of the foot and leg may be covered by any of a number of ingenious procedures. If primary or secondary closure is not feasible due to tension upon the wound margins, free grafts of skin may be used expeditiously. In this manner the open wound of the extremity is converted into a closed wound, using a "dressing graft" of partial thickness skin. If this be sufficiently thick, be over a recessed area, or be over semi-resilient tissue, such a dressing graft may be permanent. If, however, it be over a bony convexity, its breakdown may be anticipated, although this is not universally true. A transplant to the plantar surface of the foot which utilizes similar tissue from the inner pedal region below the medial malleolus is advantageous, as this area has a thickened epidermis and connective tissue in the dermis which is more compact than skin on all other areas of the body except the palm. The donor defect, then, is covered with a free graft of partial thickness skin from another area.

The Use of Adjacent Pedicled Flaps. To surface the injured lower extremity with soft tissue that will bring increased vascular circulation to the injured area as well as afford a thick resilient pad of full thickness skin and subcutaneous tissue, one must use a pedicled flap. Of these, adjacent flaps are the most expedient but they are not always successful. The advantage in using local flaps is that only one operation is usually required, and postoperative immobilization can be carried out using a single leg cast. Local flaps of several types may be used, such as the rotation flap, the lateral advancement flap, or the bipedicled sliding flap.

A rotation flap is outlined in a curvilinear fashion with the perimeter of the flap approximately four times as long as the distance the pedicle must be advanced. A rotation flap depends upon the circular torsion of the tissues for shifting, much in the manner of the opening of a fan. No secondary or donor defect results. A rotation flap should be shifted immediately to utilize maximum tissue resiliency. One does not perform a preliminary outlining operation for the rotation flap, for to do so limits the intrinsic stretch of the flap upon which it depends for advancement.

A lateral advancement flap may be used to surface defects of the lower extremity. This is a roughly square flap which is advanced laterally about 45 degrees without stretching or torquing the soft tissues of the flap. A triangular donor defect results from the use of this flap for which a free thick-split graft of skin is used. Contrary to the rotation flap, the advancement flap on the leg should not be shifted immediately but should be prepared by previous operation or operations designed to enhance circulation, outlining the flap by incision and suture.

An adjacent, bipedicled sliding flap may be used to surface the leg or thigh by making a relaxing incision parallel to and at some dis-

tance from the margin of the wound. The intervening skin and subcutaneous tissue are undermined upon the fascia of the leg or thigh, and the bipedicled flap is shifted forward to cover the wound. A large secondary defect results, approximately twice the size of the original wound, which must be surfaced with a free thick-split graft of skin. For safety, a preliminary outlining operation should be undertaken. The advancement lateralward may be made in caterpillar fashion with greater safety as suggested by Crawford [*1*].

Adjacent flaps have the advantage of requiring but a single operative procedure and involving but one extremity; their use obviates the need for heavy devices of immobilization such as are required for pedicled flaps from a distance by means of which the two extremities are locked together.

An adjacent flap should not be attempted, obviously, if the dimensions of the wound are greater than the soft tissue available or if the secondary defect produced by its use lies over a site of potential breakdown in the future. The soft tissues of the leg are relatively inelastic and often cannot be made to rotate or slide sufficiently far without producing tension upon the margins of the flap, a happenstance which initiates necrosis. Certainly, the central part of the bipedicled sliding flap undergoes necrosis uncommonly often, suggesting that the pedicle was either too narrow and/or had been sutured under undue tension.

Often, the successfully transplanted adjacent flap is so small as to defeat the purpose for which it was designed. Usually adjacent flaps merely rearrange the soft tissue upon the damaged extremity when larger blocks of soft tissue with their not inconsiderable blood supply could be brought in from a distance more profitably.

The Use of Pedicled Flaps from a Distance. If the use of an adjacent flap has been vetoed for any of the aforementioned reasons, one must bring in a pedicled flap from a distance. Donor areas that may be utilized are the ipsilateral thigh or forearm, the torso, or the contralateral leg or thigh.

The ipsilateral thigh may be used to form a thigh pedicle which may be tubed or constructed as a lined, open pedicled flap. Such a pedicle may be transplanted distalward in caterpillar fashion (tumbler flap [*2*]), or the wrist may be used as a temporary carrier.

The ipsilateral aspect of the forearm may be used as a donor area for a pedicled flap of limited size.

Because of its expanse of soft tissues and because the donor defect is clothed and out of sight, the torso is the great heartland of pedicled flaps. These include the broad jump flap [*3*] which is attached to the forearm carrier along one side of the rectangular flap, the marsupial flap [*4*], the Mustarde flap [*5*], or a tubed pedicle [*6,7*] from the abdomen. All of these flaps require transient nourishment from a carrier, usually the wrist or forearm, which transports the soft tissue to the distant part.

Cross-Leg and Cross-Thigh Flaps. A pedicled flap from the contralateral leg or thigh which is transplanted by the cross-leg or cross-thigh procedure has gained increasing favor during and after World War II. A large block of skin and subcutaneous tissue with its accompanying vascular supply can be transplanted from the opposite lower extremity with relatively little inconvenience or discomfort and with a high degree of success.

Criteria of feasibility: A cross-leg flap procedure can be carried out if the opposite calf or thigh is undamaged by scarring, is free from eczyma, cellulitis, varicosities, thrombophlebitis, or obliterative arterial disease, and if the donor defect has sufficient surface area to supply a pedicled flap of the required size. In addition, the knee and hip joints must possess sufficient mobility so that the two extremities may be brought together in close proximity at the point of pedicled attachment.

Indications: If a cross-leg or cross-thigh flap is feasible as judged by the aforementioned criteria, its use is indicated if soft tissues adjacent to the wound are not available due to scarring, if the wound of the extremity represents breakdown of a previously applied thick-split graft of skin, if scar epithelium alone surfaces a wound over the bony promontories of the tibial crest or the malleoli, or the mobile Achilles tendon; such a flap is also indicated if further reconstructive work is to be carried out through the transplanted soft tissues. Only full thickness skin and subcutaneous tissue provide a sufficiently vascular bed to support an additional transplant of bone, tendon, or nerve, and only such tissue can withstand the operative retraction inherent in the transplantation of additional grafts.

Further, cross-leg or cross-thigh flaps are

indicated as an immediate procedure in compound fractures of the tibia in which there has been loss of soft tissues over the site of fracture, or if the soft tissues of the compound wound cannot be closed without tension. These flaps are also indicated in cases of non-union of the tibia with overlying scarring, and, indeed, cases have been reported in which union resulted following soft tissue transplantation alone, due to the increase in local blood supply.

Cross-leg flaps can be performed at the same time that bone grafts are inserted, and a small number of these successfully combined procedures have been reported [8]. I have one such case in my series.*

Certainly the crux of the treatment for compound fractures of the leg is skin healing, for skin coverage in compound fractures of the tibia is as important as treatment of the bony fracture. Certainly the coverage and the bony problems can be handled together by team effort between orthopedist and plastic surgeon. In a recent series reported by Cuthbert [8], cross-leg flaps were transplanted at the same time as bone grafts in nine instances. Five were completely successful, two patients needed two bone grafts, and one needed three bone grafts.

Selection of available methods: In surfacing soft tissue defects of the extremities, the simplest method applicable should be utilized first. If this method does not prove permanently satisfactory, a more complex type of coverage of the pedicle type must be resorted to. The procedure chosen should be selected in ascending order of complexity, with preference given to the simplest solution as measured by chance of success, by length of hospitalization, and by comfort of the patient. The adjacent flap may be chosen because it may require but a single operative step and simple postoperative immobilization. Cross-leg and cross-thigh flaps are advantageous because they require but one major transplantation whereas migration of pedicled flaps from the torso requires two major transplantations, first to the carrier and then to the extremity.

THE CROSS-LEG FLAP PROCEDURE

The Pattern. The cross-leg flap procedure is one of precision in which each stage is planned in advance. First, the defect to be surfaced must be outlined with ample margins so that a large pedicled flap may be transplanted to this area. A small pedicle means that the perimeter scars are in close approximation, producing a scar-locked edematous flap. It is justifiable to sacrifice normal skin in order to enlarge the size of the immigrant flap. One should attempt to move back the peripheral scars by removing all scar that is deeply fixed from the injured foot or leg.

The defect, then, is outlined amply, using dye or ink. A pattern [9] is made of the half of the defect to be covered by the distal free end of the flap, leaving an excess of pattern to compensate for possible necrosis. Beside marginal necrosis, the flap must be amply constructed to compensate for the space occupied by the plaster of Paris casts. The flap should be constructed roughly half again as large as the defect. The remaining half of the pattern is left long with parallel sides. The long axis of the defect becomes, therefore, the width of the flap at its base.

The distal end of the pattern is made adherent to the defect using liquid adhesive or adhesive strapping. The patient's legs are brought into juxtaposition, and, by trial and error, the proximal end of the pattern (which represents the base of the flap) is laid upon the intended donor area, when the patient has assumed the most comfortable postion possible. If the donor site chosen will provide a flap of required size, the base of the pattern is fixed to the donor area and its distal end is removed from the defect. The extremities are abducted, and the distal end of the pattern is allowed to fall onto the donor area where it is outlined with dye or ink.

Donor Areas for the Cross-Leg or Cross-Thigh Flap. When the lower extremity is used as a donor area for a cross-leg or cross-thigh flap, the entire circumference of the calf or thigh presents itself for possible donor sites for prospective pedicled flaps. The size of the usual pedicled flap required allows for three possible donor areas upon the leg (medial, posterior and lateral aspects), whereas the thigh affords four possible donor sites (anterior, medial, posterior and lateral aspects). From injection studies performed upon cadavers, the cutaneous and subcutaneous arterial vascularity has been studied in these areas and has been found to be most abundant on the medial aspect of the calf and the anterior aspect of the thigh [10]. The arteries that supply the medial third of the calf

* Patient operated upon with Dr. Frederick Lee Liebolt who performed the bone graft.

are the posterior tibial, the medial inferior genicular, and the saphenous. The dip that the medial inferior genicular artery takes caudally under the medial condyle of the tibia allows this vessel to supply superficial tissues of the calf to an effective degree. The anterior aspect of the thigh is a vascular area supplied most commonly by the third deep perforating branch of the femoral artery.

Without manipulating the extremities into a "martyred" position, it is possible to transplant a pedicle from the medial part of the calf and anterior part of the thigh to any area of the foot and leg. One is loath to use the medial aspect of the calf as a donor site in the female patient, however, because of the cosmetically undesirable donor concavity that it produces. A pedicle from the medial aspect of the calf will supply any area of injury upon the foot or leg. All of the calf flaps can be planned so that their bases are proximal or anterior with the exception of flaps to be used for surfacing the plantar aspect of the foot and the posterior or lateral sides of the leg. In the former, a distally based flap is needed, while in the latter instances, posteriorally based flaps are needed. The cross-thigh flap will cover defects easily on the anterior or posterior aspect of the leg, in the former instance by pedicles that are based distally and in the latter instance by those that are based proximally.

Preliminary Outline of Pedicle by Incision and Suture. Immediate transplantation of a flap from the calf or thigh may be carried out successfully in some instances, especially in the younger patient [*11*]. However, if the pedicle be longer than it is broad, if it is to be based in a retrograde fashion (i.e. distally), and if the peripheral vessels of the donor extremity are of poor caliber (evidencing sclerosis with no peripheral pulses discernable), a preliminary operation to outline the flap by incision and suture should be undertaken to reinforce the vascularity of the pedicled flap.

The first elevation of a pedicled flap as a preliminary step to enhance circulation was performed in 1854 by Dr. Frank H. Hamilton [*12*], the man who devised the cross-leg procedure.

The rationale behind this procedure is based upon the assumption that a temporary circulatory deficiency will stimulate a compensatory increase in circulation which will maintain the viability of the pedicle while under the adverse circumstances imposed by transplantation. It is thought that incision, elevation and suture of the pedicled flap will improve local circulatory efficiency. Tissue clearance is a somewhat confusing concept and implies the ability of the local blood and lymph circulation to remove and supply freely the diffusible substances from and to the soft tissues. This two-way flow of nutrients and metabolites depends upon factors which influence equilibrium between capillary blood and lymph, upon diffusion rate, diffusion distance, the capillary-tissue interface, and filtration and absorbtion rates of extracellular fluid.

Recent work by Hoffmeister [*13*] indicates that the most successful vascular enhancement of a pedicled flap is by outline of the pedicle upon three sides, by undermining and then by replacing it in its bed. Hoffmeister has found that in all types of preparation of flaps there is a rapid decline of circulatory efficiency, a gradual increase to a peak that is well above the normal circulation of that area, and then a rapid decline to normal values within three to five days. If the pedicle is outlined upon three sides and undermined, and increase in circulatory efficiency of 126 to 180 per cent occurs from seventeen to sixty-three days following operation. However, if two sides of the pedicle are incised and the flap undermined, circulatory efficiency rises to a peak of 98 to 158 per cent from ten to twenty-one days following the operative procedure. This implies that a preparatory operation upon the pedicle should be performed three weeks before transplantation of the pedicle if total elevation is accomplished, and two weeks before transplantation if two sides are incised and the flap undermined. However, total elevation in older people or in patients with flaps that are longer than they are wide, may plummet the decline in circulatory efficiency to the brink of necrosis.

Vascular augmentation of pedicled tissue has been achieved artificially by DeHaan and Stark [*14*], using histamine in an ointment base which is induced into the soft tissues percutaneously by iontophoresis. This method of vascular reinforcement is achieved unequivocally after eight daily treatments. A current of 5 ma. run for ten minutes by direct ion transfer will drive the positive histamine ion out of solution into the ductile orifices where it produces a powerful vasodilatory effect in the soft tissues of the pedicled flap.

Preoperative Application of Plaster of Paris Casts. Transplanting the cross-leg or cross-

thigh flap is technically the single difficult step in this procedure. Transfer of the pedicled flap and subsequent immobilization of the lower extremities pose an engineering problem of first magnitude. To facilitate and expedite the transfer and immobilization, preoperative application of plaster of Paris casts is advocated. Casts can be applied to the individual leg prior to surgery. In this manner, adequate padding can be placed about the knee, the tibial crest, the superficial peroneal nerve, both malleoli and the heel. As the patient remains in his immobilizing device for approximately three to four weeks after transplantation of the pedicle, it is essential that he be comfortable and that his troubles not be compounded by pressure sores developing from inadequately applied casts. A number of suggestions have been made for improving and facilitating the immobilization. Some surgeons have used overhead pulley suspension to maintain postoperative position. Others advocate use of a pin placed through the recipient tibia, attached to overhead suspension. Because of the weight of the two lower extremities, however, plaster of Paris must be used for immobilization. Macey [*15*] first suggested the use of preoperatively applied plaster of Paris casts, and these were advocated again by Ghormley and Lipscomb [*16*] and by Stark [*17*]. Devices used to facilitate the locking of the individual leg casts consisted of incorporating universal joints (Matthews [*18*]) or a perforated metal upright into the casts which were then joined together by a perforated metal bar (Stark, [*17*]). Letterman [*19*] applied splints of plexiglass prior to operation. Dencer [*20*] utilized a pair of metal shoes into which the patient's feet were placed. These were incorporated into wrap-around rolls of plaster of Paris at the end of the procedure. Kernahan [*21*] and Zdravic [*22*] incorporated a Roger Anderson apparatus in their plaster of Paris casts.

Utilization of preoperatively applied, mated, plaster of Paris casts is advantageous because the casts are padded adequately and hence are more comfortable for the patient. This single step reduces the surgeon's time in the operating room for the application of a suitable cast following transplantation of the pedicle at least doubles the operative time. In addition, wrapping the two lower extremities joined by a pedicle flap with plaster of Paris considerably traumatizes the flap. Too, the pedicled flap must be kept open for inspection while the extremities are being casted if the proper position for the flap is to be obtained, but this means that the wound is contaminated by plaster drippings. Since there have been cases reported of tetanus developing from the application of unsterile plaster of Paris, this is obviously inadvisable. However, if the casts are applied to the individual extremities before operation, additional circularly applied plaster and perhaps a metal or wooden strut at places where the casts are distant from one another are all that is required to complete the immobilization. The pedicle may be covered with a sterile dressing at the conclusion of the procedure, thereby reducing the possibility of infection. Infection has not been a problem in any of the eighty-six cross-leg flap procedures with which I have been associated.

Since the operation is performed through windows in the casts, these apertures appreciably aid in the postoperative care of both the pedicle and donor defect in dressing, in removing sutures and in wound cleansing.

The cross-leg flap procedure is one in which each step is planned in advance. The defect is a fixed point and, by preliminary location of the pedicle by pattern, so is the donor defect. Then the extremities are placed in their postoperative position. The position is checked using the original pattern. The proximal end of the pattern must rest upon the base of the donor site with its distal end resting upon the defect so that the entire pattern, with excess to spare, covers the defect. With the patient conscious, cooperative and in the supine position, the patient abducts the injured leg and fixes his knee and ankle to prevent movement. The injured extremity is padded at the appropriate places and the cast applied. A window is cut out of the plaster over the defect so as to expose it fully. Now, the legs assume the postoperative position once again. This time the donor leg is abducted with the knee and ankle fixed. An additional plaster of Paris cast is applied and a window is cut over the donor area. The legs are brought together again and the pattern is used to check the position of the casted extremities. The interposition of two layers of plaster may separate the donor and the recipient areas by several inches; to offset this the flap has been made abundantly large. One must mark the points of separation upon the two casts and cut away the plaster in these areas. Now the casted

legs can be brought in near juxtaposition with only the padding interposed.

We have used the calf of the contralateral leg more and more as a donor site, with the extremities in a side-to-side position. When this position is used, the two casts are incorporated into one immobilizing device by using circularly applied plaster at the points of juncture of the two casts, proximal and distal to the windows. If a cross-thigh flap is used, the point of juncture of the two casts is wrapped circularly and the points at which the casts are most distant from one another are united using a wooden strut reinforced with plaster. A variation in this method of immobilization consists of incorporating within each individual leg cast semicircular malleable metal bands to which are attached a short vertical metal upright containing a single perforation. These malleable metal bands are wrapped into the cast, leaving the perforated vertical metal upright extruding from the plaster. The casts are incorporated into a single device at the time of operation, cutting the stockinet drape and allowing the vertical uprights to perforate through. A strong antiseptic agent is used to cleanse them. The two casts are then locked together, using a perforated metal bar which is bolted to the vertical uprights using a bolt and wing nut. This bar, applied at operation, allows the legs to be self-maintained in the desired position before transplanting the pedicled flap, and thereby spares the surgical assistants the extremely tedious and heavy job of holding the casted legs in their proper positions [*23*].

Transplantation. At operation, preparation of donor and recipient areas is carried out using a stainless, antiseptic solution so that the color of the pedicle may be assayed as it is elevated. The casted extremities are draped using two layers of sterile, six-inch stockinet, the distal end of which is closed. Stockinet is rolled over the casts and the extremities are placed upon a sterile sheet. Over the two windows the stockinet is cut peripherally with scissors from the center of the window forming pie-shaped sectors which are tucked between the cast and the skin of the legs, producing neat apertures through which the operation is performed.

The donor area for a thick-split graft is prepared and draped appropriately. Usually the lower part of the abdomen is selected so the compression dressing used will not embarrass circulation to the extremities.

In elevating the pedicled flap, the distal end must be elevated first so that the flap may be repositioned and its transfer delayed if signs of circulatory embarrassment manifest themselves One such sign of circulatory embarrassment is persistent venous bleeding from the dermal capillaries and venules [*24*]. If the dermal vessels exhibit only venous blood, the efferent circulation has been overextended and the pedicle should be replaced. In the pigmented patient, in whom cyanosis of the flap cannot be ascertained, dermal bleeding serves as a valuable index. Bleeding from the flap can be compared with control bleeding from the skin on the opposite side of the wound. Additional signs of danger which make replacement mandatory with delay of transplantation are mottled discoloration of the flap or cutis anserina which indicates discharge of the sympathetic nervous system due to hypoxia.

In transfer of the pedicle, care must be exercised to surface not only the donor wound but also the under surface of the bridge of the pedicle which is not in contact with the donor wound. This may be accomplished in several ways. The scar tissue from the donor wound or the cutaneous surface adjacent to the wound may be turned back and sutured to the under surface of the flap. The most expeditious and satisfactory way is to surface this area with thick-split skin [*25*].

Care of the Pedicled Flap Following Transplantation. During the first twenty-four hours postoperatively, the position of the pedicled flap must be observed at frequent intervals for signs of circulatory impairment as evidenced by cyanosis or edema of the flap. Such evidence of circulatory impairment may be treated at once in several ways. It is known that formation of a pedicle, in effect, sympathectomizes it; hence, the blood vessels within the flaps are, for a time, little more than patulous vascular sinusoids. Therefore, the filling and emptying of the vascular tree of the pedicled flap may be aided by gravity by using an oscillating bed. In addition, clearance from a pedicle of venous blood and edema may be facilitated by using a spreading factor (hyaluronidase) which will relieve tissue tension that may promote vascular thrombosis. Circulatory impairment is often due to stretch or torque of the pedicled flap and this demands immediate alteration of the position of the extremities.

Following transfer of the pedicled flap, the

patient may experience discomfort in knee, ankle and, possibly, in the hip joints. Discomfort is in direct relationship to the degree of flexion. Dry heat and massage to accessible areas will allay pain. Agents such as whiskey or tranquilizing drugs aid these patients. If an overhead trapeze is available, the patient will be able to shift himself in bed. At the end of one week's time, the patient may be allowed in a wheelchair or upon a litter but then only if legs are extended horizontally. By using the wheelchair, the patient may gain access to the bathroom and be allowed toilet privileges but again only if the casts remain extended horizontally onto a chair. Until the pedicle is separated, the extremities must not be allowed to become dependent.

Severance of the Cross-Leg Flap. Some surgeons sever a pedicled flap at the earliest date that the pedicle will survive with its new vascular autonomy. So much is at stake for the patient and the surgeon, however, that it is well not to hurry this stage of the procedure. An arbitrary time of approximately three weeks should elapse before the severance of the pedicled "umbilical cord" is anticipated, and even then it is safer to cut across the base of the pedicle in stages. If the pedicle is transected completely at one operation, one frequently encounters "severance slough." Jayes [*26*] has pointed to the fact that approximately one in six of his patients had partial loss of the margin of the flap at the time of severance of the pedicle. This is due to the fact that recent vascular anastomoses across the inset scar are illy able to support the pedicle in its new state of autonomy without being conditioned by partial transection of the pedicled base.

As indicated, severance slough can be avoided by partial transection in stages. This procedure is best performed by using local anesthesia with the patient remaining in his plaster of Paris cast. Because the extremities are in virtually intimate contact, hemostasis of blood vessels at the base of the flap by conventional clamp and ligature is exceedingly difficult. The use of a cautery with a cutting current circumvents this difficulty. I prefer to cut the pedicle down upon alternate days encompassing three operative procedures. After the pedicle has been transected completely, the casts are removed. The wounds of severance are dressed using wet dressings, applied at least four times daily. Several days following complete transection, the pedicle is trimmed of all granulation tissue, any remaining immobile skin is removed from the defective wound and the flap is inset. At all operative stages, the pedicled flap is sutured with a horizontal dermal mattress suture which upon the side of the flap picks up the dermis only and does not scar its cutaneous perimeter. Following inset of the pedicle, wet dressings are again used upon the flap and donor wounds for several days.

Postoperative Care. Again massage and dry heat are applied to the ankle, knee and hip joints, for some patients may experience transient hypostatic arthritis as a result of their immobility.

Massage using a protective emollient (cold cream, lanolin or cocoa butter) with deep local friction is necessary to both the flap and the grafted donor site after healing has occurred. Zinc oxide, calamine, or hydrocortisone ointment should be used for eczema. Callus, which is prone to form at the margins of tissues transplanted upon the plantar surface, is treated using pumice.

The extremities should not be allowed to be dependent sooner than two and a half weeks postoperatively and never unless supported externally. At a minimum, support consists of two thicknesses of elastic bandages or preferably, tailored elastic stockings for each extremity. In most instances elastic support of the extremities must be worn for the duration of the patient's life. External support produces a pumping effect, providing *vis a tergo* necessary to promote venous and lymphatic drainage. Certainly exercise is necessary if edema of the extremities is to be prevented. This is illustrated by persistent edema in cases of ankylosis of the ankle joint in which the pumping action is missing. External support means external protection also. This is important because trauma is the chief cause of recurrent ulceration.

In our cases, cutaneous sensation returned to the pedicled flap before it did to the thick-split skin graft, and it did so in a centripetal fashion. Until full sensation has returned to both the pedicle and the donor graft, these transplants must be protected from extremes of cold and heat, and the application of heating pads to these sites or their exposure to the rays of the sun is contraindicated.

The personal equation enters into these procedures. Pedicled flaps will be successful and definitive in the conscientious patient but they

will fail in the careless patient who is not fastidious about his personal hygiene, for the factors of dependence, trauma and lack of cleanliness militate against the durability of transplanted tissues upon the foot or leg.

Series. I have been associated personally with eighty-six cases of cross-leg and cross-thigh flaps. There have been two failures. One failure was due to generalized, advanced arteriosclerosis in a patient upon whom not only a cross-thigh flap but an abdominal tubed pedicle underwent necrosis. This failure was due to the poor selection of patient. The second failure occurred because the flap which manifested signs of circulatory insufficiency should have been returned to its bed. Instead, it was sutured under undue tension in a case performed before an operative clinic, illustrating the fact that unnatural pressures may cloud a surgeon's judgment.

The oldest patient operated upon was a sixty-one year old woman and the youngest was a boy of five years. In patients in otherwise good health, age is no contraindication to the use of the cross-leg or cross-thigh flap. In the older patients, however, it is best to utilize the medial aspect of the calf as a donor site, placing the extremities in the relatively comfortable side-to-side position. In addition, it is well to prepare the pedicle several times by incision and suture.

SUMMARY

The cross-leg flap will provide pedicled soft tissues and an abundant blood supply to the opposite foot or leg without contorting the patient into a martyred position. This procedure is increasingly useful in cases of civilian trauma, even in the very young or the elderly patients. The criteria of feasibility and indications for the cross-leg flap are enumerated. Important technical steps are described which will enhance the comfort of the patient and insure the success of the procedure.

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Polyurethane Polymer—Its Use in Fractured and Diseased Bones

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CONSIDERABLE interest has been shown by several groups of investigators [1–4] in an attempt to obtain a suitable synthetic or plastic that could be poured in liquid form, set within a reasonable length of time and have the qualities of strength, osteogenesis, non-toxicity, cohesiveness and ease of handling required during surgery.

Many types of plastics have been used safely for a wide variety of medical purposes, which suggested the application of such substances to the problem of osseous lesions. Of the several possible materials which approach ideal requirements, rigid polyurethane foam (ostamer*) is our compound of choice.

For the purpose of producing a dense, rigid, cellular foam for orthopedic use, a polymer is prepared by reacting a trihydroxy resin with an excess of diisocyanate. This polymer is mixed at the time of surgery with a catalyst. Carbon dioxide is liberated, producing a sponge-like compound with 7 to 10 per cent cellular structure. The polymer and the catalyst are in liquid form, and when mixed in a 1:4 ratio, result in a volume approximately three times that of the original. No heat is liberated.

It is apparent chemically that the polymer bonds to the surfaces to be held, bridged, filled or strengthened. The ostamer, in and during its formation, becomes an intimate part of the bone. It is this property that differentiates it from a glue, adhesive or common cement-type bonding.

The rigid polyurethane foam (ostamer), which at this time is considered the best for orthopedic use, tests as follows: bond strength to bone, from 170 to 190 pounds per square inch; tensile strength, 800 pounds per square inch; compressive strength, 20,000 pounds per square inch with 10 per cent deflection; density, 25 to 30 pounds per cubic foot; shear strength, 500 pounds per square inch; flexural strength, 1,000 to 1,200 pounds per square inch.

Following satisfactory tests for strength of ostamer, toxicity studies were begun. Published reports by Fuchs and Valade in 1951 [5] and by Reinl in 1954 substantiate the non-toxicity of the polyurethanes. Guinea pig intraperitoneal inoculations performed by the authors were all negative for toxicity. Further study on dogs was then indicated. To date there has been no evidence of toxicity to the experimental animal (dog, rat, guinea pig), and the material elicits little or no tissue response at the site of implantation.

Polyurethane was applied to surgically created defects in the radii and femurs of dogs, and these animals were followed up radiologically and histologically. Polyurethane appears to have satisfied requirements for fixation of the fragments without inhibiting osteogenesis.

The use of ostamer is best restricted to those anatomical regions where adequate hemostasis, by tourniquet or other established technique, may be secured.

Sufficient fixation for wound closure occurs in twenty to thirty minutes. Complete hardening requires eighteen to twenty-four hours, during which time a posterior splint might be used. After a twenty-four- to forty-eight-hour "curing" time, the stability of the bonded area is such that weight bearing may be initiated. The chemical remains radiolucent.

The type of operation and contemplated chemical fixation were explained thoroughly to

* Trademark of the Wm. S. Merrell Company, Cincinnati, Ohio, for its rigid polyurethane foam.

FIG. 1. Case 1. Acute oblique fracture of the right distal tibia and fibula.

each patient, and each patient accepted the procedure readily. A description of six patients treated by this method follows.

CASE REPORTS

CASE 1. J. D., a twenty-nine year old man, suffered an acute oblique fracture of the right distal tibia and fibula. (Fig. 1.) Operation was performed at the Hahnemann Medical College and Hospital on October 29, 1956. The fracture site was exposed. A reverse inlay cortical graft was removed. The intermedullary canal was curetted and the site was made ready for the "pour" of ostamer. Two stainless steel pins were placed in the intermedullary trough (for additional strength). (Fig. 2.) The catalyst was added and the polymer was mixed. The "pour" was made and the medullary canal was filled. Rapidly, the reverse inlay graft was inserted and maintained by two Loman clamps. The chemical was allowed to expand and set. Excess polymer was removed. The wound was closed. A posterior plaster splint was applied. Antibiotics and routine postoperative care were given.

On November 1, three days postoperatively, the splint was removed. X-ray films were taken with the patient in the supine position and then in a position of full weight bearing on the right leg.

FIG. 2. Case 1. Prepared operative site with reinforcing pins in tibial trough.

(Fig. 3.) The position of the fracture was maintained satisfactorily. The patient was bearing full weight without crutches in two weeks. A short leg brace with ankle stirrups was applied and worn for three months. X-ray films taken one year postoperatively revealed complete healing. (Figs. 4 and 5.) Complete kidney and liver function tests and bone marrow studies two years postoperatively were completely negative for any toxicity. The patient has been driving a moving van and moving heavy equipment.

CASE II. D. M., a fifty-eight year old man, sustained a compound fracture of the left tibia in September, 1955. A frank non-union of the midshaft of the left tibia developed. (Fig. 6, *left.*) The patient had been wearing a cast for fourteen months prior to operation. A posterior draining sinus at the level of non-union existed from the time of fracture.

On November 5, 1956, open reduction of the non-union of the left tibia was performed. A portion approximately ½ inch in length was removed from the fibula. The tibia was exposed. A trough was made at the site of the non-union by removing a cortical graft 1 by 15 cm. superiorly. The site of the non-union was freshened by removing approximately ⅛ inch of bone from each end of the frac-

FIG. 3. Case 1. X-ray films taken three days postoperatively.

FIG. 4. Case I. X-ray films taken twenty-four months postoperatively.

FIG. 5. Case I. Photograph of patient fully weight bearing twenty-four months postoperatively.

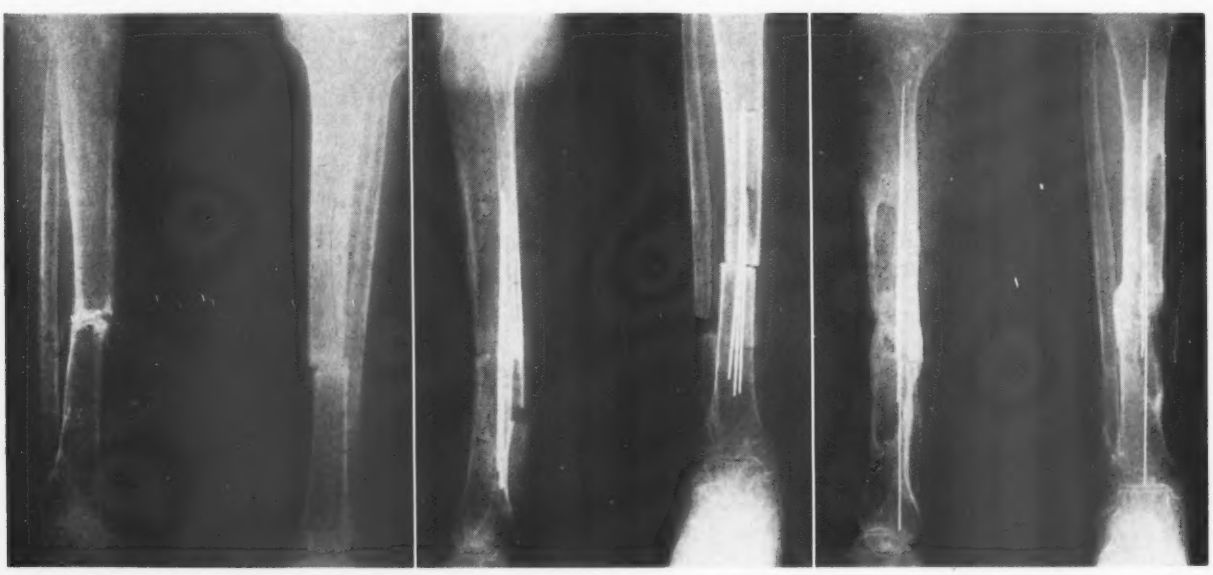

FIG. 6. Case II. *Left*, non-union of the mid-shaft of the left tibia. *Center*, postoperative x-ray films. *Right*, x-ray films taken sixteen months postoperatively.

ture site. The medullary canal of the tibia was cleaned thoroughly and dried. Three Kirschner wires of light weight were laid in the medullary canal, and the ostamer was poured into the medullary canal. Cortical grafts were reversed, placed in position and held with Loman clamps. After the plastic material had hardened, the excess was removed from the outer portion of the tibia. The wound was then closed. A posterior plaster splint was applied for forty-eight hours.

The record shows that at the time of operation the material draining from the sinus contained pus cells, but no organisms were cultured. Antibiotics were administered. The drainage persisted. Immediately postoperatively, x-ray films showed good position. (Fig. 6, *center*.) The patient was ambulant with a brace two weeks postoperatively. The last x-ray examination, made in March, 1958, showed complete union. (Fig. 6, *right*.)

CASE III. P. O., a forty-three year old woman, was in a virtually moribund condition, suffering

FIG. 7. Case III. Postoperative x-ray film.

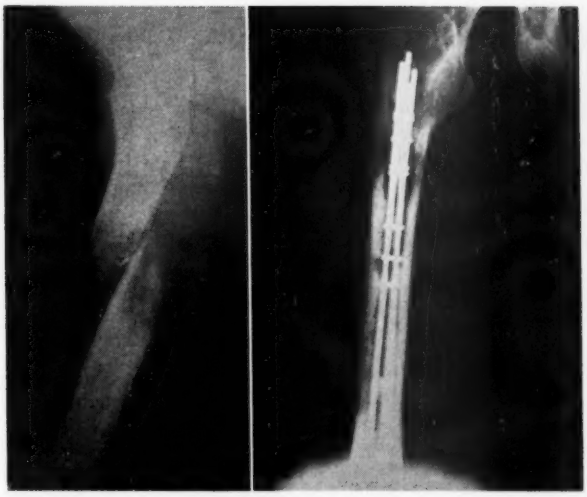

FIG. 8. Case IV. *Left*, pathologic fracture of the right femur. *Right*, postoperative x-ray film.

from metastatic adenocarcinoma, which on October 5, 1957, produced a pathological subtrochanteric fracture of the left femur. Four months previously the patient had suffered a subcapital fracture of the neck of the right femur.

On October 8 an open reduction of the subtrochanteric fracture of the left femur was performed. An inlay graft was cut across the fracture site. The neck of the femur was gouged. Two steel rods were bent into shape and placed in the medullary canal to extend upward into the neck. The plastic material was mixed and poured into the medullary canal, upward into the neck of the femur. The inlay graft was reversed and put into place across the fracture site. The bone fragments were held in place with clamps until the ostamer had hardened. The wound healed without complication. The patient was completely relieved of pain in the operated area and, even though bedridden, was able to perform her activities of daily living in comparative comfort. (Fig. 7.)

CASE IV. G. McG., a fifty-two year old woman, had multiple myeloma with spontaneous fractures of vertebrae, right humerus and right femur at the junction of the proximal and middle thirds. (Fig. 8, *left*.)

On November 26, 1957, open reduction of the right femur was performed. The operation performed was the same as in the previous cases, with removal of a cortical segment and its replacement as a reversed inlay graft. The right femur required no traction or cast postoperatively. (Fig. 8, *right*.) Physical therapy was begun forty-eight hours after surgery. The patient had little or no complaints referable to the right femur, but because of general debility and pain caused by the fractures of the right humerus and the spine, she remained bedridden. The wound healed uneventfully. The patient died six weeks postoperatively.

CASE V. S. C., a sixty-eight year old psychotic man, had delayed union of a supracondylar fracture of the right femur. (Fig. 9.) He had been in a hip spica for seven months. It was imperative, from a neuropsychiatric standpoint, to have this patient ambulant as soon as possible.

On April 11, 1958, operation was performed. The same operative procedure was carried out as in the previous cases. Compressive dressings were applied postoperatively and antibiotics were given with routine postoperative care. The patient was ambulatory three days postoperatively and is allowed to walk as his mental condition permits.

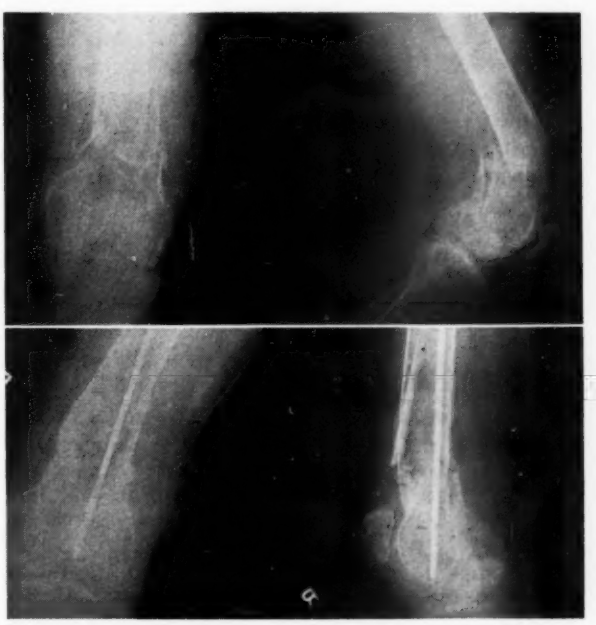

FIG. 9. Case V. Delayed union of supracondylar fracture of the right femur.

FIG. 10. Case VI. Non-union of the mid-shaft of the tibia of seven years' duration.

FIG. 11. Case VI. X-ray films taken immediately postoperatively and four months postoperatively.

CASE VI. A. G., sixty-six years of age, had non-union in the mid-shaft of the tibia of seven years' duration. (Fig. 10.) Two bone-grafting procedures to the site had previously been attempted but had been unsuccessful. The patient had been wearing an ischial caliper non-weight bearing brace for seven years.

Operation was performed on May 1, 1958. The fibula was left intact and the sclerotic bone at the site of non-union was excised, leaving a defect approximately 1 inch in the tibia. The bone was not shortened and no metal rods for additional strength were used. Severe testing of the ostamer was desired. A cortical graft was removed, as in the previously cited cases, and the defect was then filled with ostamer. The patient was ambulant with a short leg brace with ankle stirrups two days after operation. On x-ray examination ten weeks after operation there was bridging of the defect. Figure 11 shows the immediate postoperative appearance and amount of healing four months postoperatively.

SUMMARY

1. The application of a new polymer (ostamer) for fixation of bone in six patients is presented. One acute fracture of the tibia, three non-unions (two of tibia, one supracondylar femoral) and two pathologic fractures of the femur were united by polyurethane foam (ostamer). Results in all cases are satisfactory to date.

2. Encouraged by the results in animal experimentation (namely, osteogenic or osteosynthetic activity invading the lacunar-like framework of ostamer, with ultimate replacement of the polymer by new bone and no gross evidence of toxicity or malignant neoplasm), it was believed that in suitable, well chosen cases treatment should be by this method of fixation.

3. In all the presented cases the ostamer was well tolerated by the hosts and the strength of fixation was most gratifying to the surgeon.

4. Extensive studies in metabolic route, toxicity, pharmacology, pathology and carcinogenicity are being pursued.

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The Management of Avulsed Pedicled Skin

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SINCE the onset of the machine age the contact of rapidly moving objects with human flesh has caused injury, the tearing off of small or large portions of skin being a common one. Often the skin is left attached. The size of this attachment, which nourishes the torn free skin is not as important as the amount of trauma to the skin itself.

It is a common practice to return the torn skin to its former location after cleaning the wound. This skin looks pink, bleeds freely, and to any observer appears normal. However, later on edema occurs and in the subsequent two weeks the entire area, or a large portion thereof, becomes necrotic. These results are disturbing and a review of the pathologic physiology is in order.

In an area of traumatized skin, venous and lymphatic drainage may be more important than arterial supply. The veins are more easily injured than the arteries. Progressive venous thrombosis may occur and the lymph channels remaining may be inadequate, leading to edema. Arteries resist trauma, so that it is not the blood supply that is the weak link, but venous and lymphatic drainage. Edema increases, and the blood supply is encroached upon until the area of skin dies. This may occur slowly and gradually, so that it may not become evident for ten to fourteen days.

An additional source of trouble is in the technical maneuvers—this skin may be overstretched during the processes of resuturing or the skin may become wrinkled as it is used to fit a defect smaller than the replaced skin. Both overstretching and wrinkling of the skin interfere with its blood supply.

The blood supply of the skin has been studied by many observers. Those pedicles constructed with blood vessels supplying them proximally are the safest, especially when rapidly mobilized for transfer. Occasionally it is necessary to construct pedicles with distal blood supplies, and these are often called retrograde. In evaluating the blood supply of man-made pedicles, we look at color, examine the distal incised portions for active bleeding, and feel for warmth. Rarely, we use elaborate methods, such as infrared photography or injections of fluorescein, and examine with ultraviolet light. These methods are for the determination of arterial supply. With gentle handling and proper positioning of the tissues, we expect no interference with venous or lymphatic drainage.

In evaluating the circulation of violently constructed pedicles, we must not use the methods in evaluating man-made pedicles. Proximally based pedicles must have broad bases, and show minimal contusion. Retrogradely based pedicles are to be completely mistrusted.

Farmer [*1*] postulated that avulsed skin was damaged. He observed sloughs in normal-appearing skin which had been pedicled or avulsed violently. His method of handling such skin was to excise the fat and attachment, and utilize the skin as an immediate full-thickness graft. This procedure was much more successful than others, as will be illustrated by the following cases. All these patients were brought promptly after injury to the Beekman-Downtown Hospital, New York City.

CASE REPORTS

CASE I. This patient, a fifty year old Chinese man, caught his hand in a noodle dough mixer, resulting in a severe crushing injury and an avulsion of the dorsal skin, with bursting skin injuries to the palmar surface. The dorsal skin was defatted, cut free and replaced as a full-thickness graft. The palmar skin was sutured. There was almost complete take of the dorsal skin, but necrosis appeared in the palmar skin. This should have been treated similarly to the dorsal skin.

CASE II. A descending elevator avulsed most of the skin of this patient's left heel. Three days

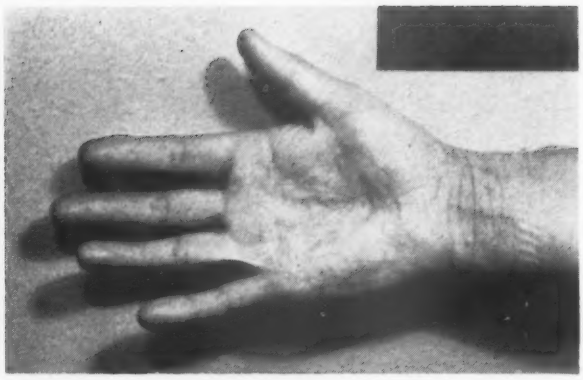

FIG. 1. Case v.

after injury the wound edges looked clean, twelve days after injury there was slight necrosis at the sutured edge, and sixteen days after injury the entire area that had been avulsed was necrotic. Repeated grafting finally resulted in healing at two and a half months.

CASE III. A heavy cover for a large ship tank fell and struck this man's leg. An avulsion and crushing of the skin and muscles of the calf resulted. At operation dead muscle was removed and some of the skin trimmed. A small defect was grafted. About the fourteenth day additional skin loss became apparent, 1 to 1½ inch in width, on the distal pedicle.

CASE IV. This patient fell against a sharp iron projection, tearing a large v-shaped laceration in his calf. The skin was excised, the fat was removed from it, and it was replaced as a full-thickness graft with a 100 per cent take.

CASE V. This man caught his hand in a conveyor belt, avulsing the skin of his entire palm, leaving two areas of attachment distally. Sacrificing the skin of an entire palm seemed to involve rather rigorous surgery, so the fat was trimmed from the skin, its attachment was severed, and the skin was sutured to the palm with a 100 per cent take. The lines and markings of this skin are as they were before but there is a little less fat beneath it. (Fig. 1.)

CASE VI. This patient was hit by a truck, and the skin of the entire foot and part of the ankle was avulsed from 3 inches below the malleoli to the toes. Since most of the toes were avulsed, and there were no soft tissues covering the distal end of the metacarpals, transmetatarsal amputation was performed. The avulsed skin was defatted and replaced from the ankle to the area of the metatarsal section. The take was better than 70 per cent, and the remaining areas were split-grafted. This patient walks and has almost normal skin on the sole of his foot. There are thin areas on his heel, but despite occasional bouts of edema due to a cardiac condition, this skin has stood up relatively well.

CASE VII. This patient had a petit mal attack while running an elevator and caught his thigh between the elevator and the walls of the shaft. Seventy per cent of the skin was ripped off the anterior, lateral and posterior surfaces of his thigh. This huge mass of skin was defatted and returned as a full-thickness graft with more than a 70 per cent take. After the remaining areas had been split-grafted, he had an almost normal-appearing thigh.

CASES VIII and IX. These patients sustained avulsion injuries to the dorsum of the hand which were treated by this same method. The results were a 100 per cent take and a 90 per cent take, respectively.

CASE X. This sixty-three year old malnourished man was hit by a bus and dragged for half a block. On admission to the hospital he presented the most severe avulsion we have treated to date. The entire skin of his right leg was avulsed from ankle to hip and hung by a pedicle, perhaps 12 inches wide, from the gluteal region. He was in deep, desperate shock and was treated for about six hours before it was thought safe to operate. This entire area of skin was detached, defatted, piecrusted and resutured. He had a very stormy postoperative course, and it is estimated that only 30 per cent of this graft took, mostly on the anterior and lateral surfaces of his leg. By multiple skin grafting, the remainder of the areas were covered in eight additional sessions.

CASE XI. A heavy object fell, causing a v-shaped laceration of the anterior tibial region in this patient. This was resutured, and the tip of the v-shaped defect showed necrosis for about 1½ inches at the end of two weeks.

CASE XII. This patient caught his foot between an elevator shaft and a wall, resulting in avulsion of the plantar surface. This was treated by standard débridement and suture, with resultant slough of most of the plantar surface of the foot.

CASE XIII. A ring this patient was wearing was caught in a truck as he jumped off, and resulted in avulsion of the skin of the proximal phalanx. Because of the good circulation of this finger, with preservation of the nerves and vessels, the skin was resutured, resulting in necrosis of the entire finger.

CASE XIV. This patient had avulsion of an area of the wrist with a distal pedicle, measuring approxi-

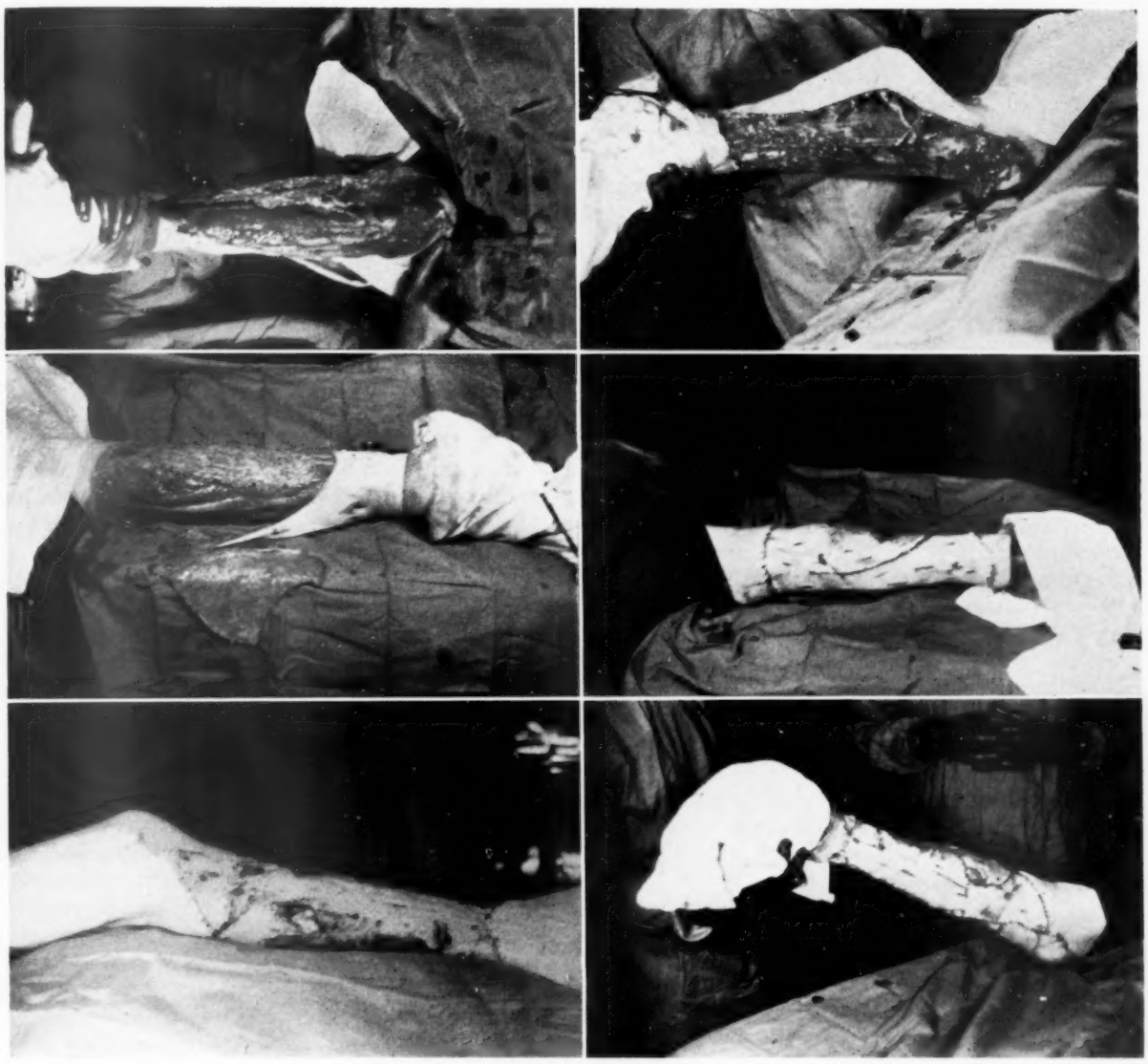

FIG. 2. Case XV.

mately 2 inches by 2 inches. This was resutured with loss of the entire flap at about two weeks.

CASE XV. This man was rolled between two trucks, avulsing the skin of the left leg from the knee to the ankle. The entire area was cut free, and the fat excised and resutured. There was a 90 per cent take of this skin anteriorly and a 50 per cent or better take posteriorly. The necrotic areas were cleaned and grafted with split grafts approximately five weeks later. (Fig. 2.)

CASE XVI. This nineteen year old boy caught his heel in an elevator shaft, with avulsion of an area measuring approximately 4 inches by 5 inches. The skin appeared to be in excellent condition and was resutured. For the first week the appearance remained the same. By the second week portions of the skin were dark, and at the end of the third week large areas of the skin were obviously necrotic. The defects were split-grafted, but as time went on this area repeatedly broke down and a pedicle graft was necessary. (Fig. 3.)

FIG. 3. Case XVI.

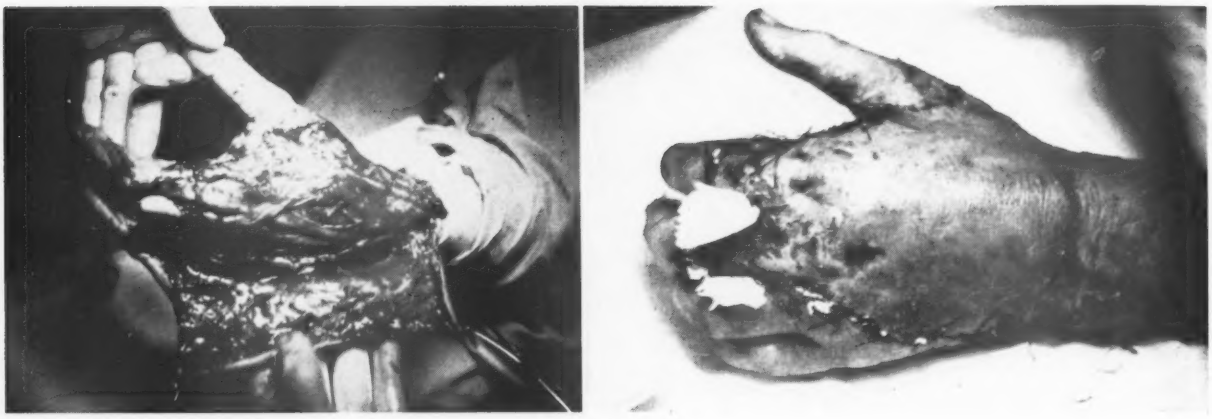

FIG. 4. Case XVII.

CASE XVII. A forty-six year old man caught his hand in an elevator brake, avulsing the skin of the dorsum with a broad attachment on the ulnar side of the hand. This was defatted and detached, and sutured in place as a full-thickness graft. A 98 per cent take and normal function resulted. (Fig. 4.)

SUMMARY

1. Skin that has been avulsed by rough trauma cannot be evaluated in the same manner as man-made pedicle grafts.

2. The location of the attachments is not as important as the degree of trauma to the skin in determining whether or not the pedicle will live.

3. It is far wiser to detach the skin, utilizing it as a full-thickness graft, than to attempt to return an avulsed pedicle to its former bed.

4. Surgeons usually using their best judgment have been fooled repeatedly by the excellent appearance of an avulsed pedicle, only to watch it slowly die over the course of the next two weeks.

REFERENCE

1. FARMER, A. W. Whole skin removal and replacement. *S. Clin. North America*, 23: 1440–1447, 1943.

DISCUSSION OF PAPERS BY DRS. CONNELL AND ROUSSELOT; STARK; MANDARINO AND SALVATORE; AND MEDL

WILLIAM L. WHITE (Pittsburgh, Pa.): I would like to re-emphasize a point that Dr. Stark made as to the limited usefulness of adjacent flaps in the lower leg. The blood supply in this area, even in a normal leg, is not too abundant, and with injury and subsequent disturbances the circulation usually becomes further impoverished. Another problem with the use of adjacent flap tissue is the convexity of the surface. These areas require additional length and stretch of skin to accommodate the convexity.

The last case Dr. Stark presented involved a combined bone graft and flap graft. In our experience, these procedures most often end unsuccessfully. The combination of a flap graft and a bone graft strains the basic concepts of surgical judgment and although they may be occasionally successful, they should be used only with great deliberation.

Perhaps the excellent presentation of Drs. Mandarino and Salvatore offers some possible future approach to this combined problem of coverage and support.

In Pittsburgh we have been more enthusiastic about thigh flaps than calf flaps. The blood supply in the thigh is better, fewer preliminary procedures are required, and the skin of the thigh is coarser. Also, since these flaps originate on the anterior aspect of the limb, the patient can lie on his back comfortably.

Due to the greater surface of the thigh, larger flaps may be obtained, and at separation or by delay the length of the flaps may be extended. While there is more flexion of the recipient hip, there is similarly less joint torsion or rotation. Plaster fixation appears to be less complicated.

We feel toilet care is less difficult in these patients because the thighs are separated. In the female, a donor defect on the thigh is preferable to a donor site below the knee.

Having recently seen some of Dr. Stark's excellent cross-leg flaps, I can only express the greatest admiration for his judgment and the flawless techniques he has developed. It is this thoroughness that has produced such excellent results—only two failures in eighty-six procedures.

I have enjoyed this presentation of a subject which is complicated by judgment, alternatives and precise techniques.

I would like to ask Dr. Medl what he means by bleeding. Venous oozing from a flap indicates congestion, not lack of supply from the arterial side. The arterial blood supply to the skin is so elaborate and presents such an excellent plexus of

dermal vessels that this overfilling is often seen. The problem, as he has pointed out, is concerned with drainage from these areas. Bleeding is often confused with venous oozing or venous congestion from these areas.

JOHN L. BELL (Chicago, Ill.): I would like to congratulate Dr. Medl on his excellent paper, calling attention to avulsed skin flaps. However, in injuries to the hand, particularly those caused by industrial rollers, avulsion of skin is frequently accompanied by severe crushing. In such cases we have not used this skin as a free whole-thickness graft because of the associated contusion.

If one replaces a flap which initially was believed to be viable, and inspection forty-eight hours later reveals that the flap has a poor color, the flap should be removed before coagulation necrosis is evident. In injuries to the hand, a primary pedicle flap may at times be necessary to cover exposed tendons. However, if areolar tissue can be shifted locally, a free graft may be applied.

We saw a patient with a severe roller injury to his hand, with avulsion, severe contusion and blistering of the skin. In this case the devitalized flaps were excised and split-thickness grafts were applied to the defect. Five days after injury the partial-thickness grafts had taken very well. The split-thickness skin grafts on the dorsum of the hand also took well. Healing occurred by primary intention.

J. W. BLUNT, JR. (Cleveland, Ohio): Drs. Manderino and Salvatore have presented a very interesting problem in their paper, about polyurethane as a binding substance for fractured bone. It represents a lot of work and a courageous, although somewhat foolhardy, application to clinical problems. However, there are many fundamental difficulties when one uses plastics in tissues; some are industrial, some legal and many are medical. They are too numerous to mention here.

Polyurethane is one of the polyester family but it is, in itself, a generic name, there being over 125 polyurethanes, depending on how the polymer is made. The authors used a rigid foam polyurethane. There are also many different foaming agents. These chemical and polymer factors will have to be considered and standardized before the authors' chemical osteosynthesis can be given widespread clinical sanction.

In their x-rays there appeared to be considerable "exuberant callus" about the area of the polyurethane foam. In some work we have done, using solid, molded polyurethane prostheses for dog hips, we found excessive edema of the pericapsular tissue, villous formation in the joint, and cortical necrosis with involucrum formation. I wonder if Dr. Manderino's "exuberant callus" is not a similar involucrum reaction to a chemical irritant.

Drs. Manderino and Salvatore have introduced an interesting compound and concept to fracture surgery. It has to be studied and nurtured, and then standardized before it can be accepted clinically. They have made a good start, but they have a very long way to go.

OSCAR PERRY HAMPTON, JR. (St. Louis, Mo.): I would particularly like to discuss the paper by Drs. Connell and Rousselot. It seemed to me that they extolled the tremendous value of antibiotics and enzymes locally, and I would like to quarrel with them just a bit. I prefer to give credit to wound débridement rather than to those measures of which they spoke so freely.

I subscribe to the concept that wound infection develops from the septic breakdown and decomposition of dead tissue in a wound. Included as dead tissue is a blood clot in dead space or collections of serum on the open surface of burns and granulating wounds.

In the cases they mentioned, it appears to me their wound infections fell either into subdivisions two or three, that is, wound suppuration or surface infection.

There are really four methods of wound débridement: (1) chemical, (2) enzymatic, (3) biological and (4) surgical. The old Dakin method of treatment was a chemical means of débridement. It did not sterilize; it merely removed dead tissue. I believe that all enzymes do is remove dead tissue.

I see very little place for the first method, chemical débridement, but I do think there is a limited place for the second method, enzymatic débridement, in removing little bits of dead tissue that probably cannot be removed surgically.

Biological débridement occurs when a wound is cleaned up spontaneously. Wound healing is a natural cellular process, provided the wound does not contain dead tissue or foreign bodies, and the body will make a real effort to sequestrate, if you will, its retained dead tissue. When this occurs, a dirty wound becomes a clean wound.

Of course, being a surgical purist, I like to think that surgical débridement is the method which should be employed in the overwhelming majority of instances.

In closing, I would like to point out that in the authors' first patient with the beautiful clean-up of the leg ulcer (and one has to compliment them on the clean-ups they obtained in these wounds) I think a forceps and a pair of scissors were used for some surgical débridement, and that the extremity was elevated to eliminate the edema, which facilitated the clean-up a great deal. I am sure that in the child who was so badly burned, the septic crusts were either washed off, soaked off or picked off. Perhaps it was the surgical débridement that cleaned up the wounds, and not the bacterial effects of local antibiotics and enzymes.

ROBERT H. KENNEDY (New York, N. Y.): I wish to make a few remarks about Dr. Medl's paper.

We all remember that Dr. Farmer brought out this point—I think about twenty years ago—and in general the surgical profession has neglected the idea.

We need to review frequently the pathology that Dr. Medl described to know why we cannot afford to put back these small or large avulsed areas of skin and subcutaneous tissue. It makes little difference how large they are. They are a great deal safer put back as defatted, full-thickness grafts, and we must remember that the defatting concerns just as much the deep side of the wound as it does the underside of the avulsed area. You have to get beyond the area of possibly injured fat.

From observing the results for a number of years, I cannot agree with Dr. Bell that we have to worry about the life of the skin itself. The deep cells of the skin are good livers; they will take if you put them against a site where there may be blood supply coming from beneath. For example, when you see avulsion of an entire lower extremity down to the ankle and replace the skin as a defatted full-thickness graft with a 75 to 85 per cent take, you have to believe that skin can stand a great deal when you consider the amount of trauma required originally to avulse the skin.

We all ought to consider that in any case of avulsion we will probably give the patient a better result by creating and applying a full-thickness graft.

Thomas Bartlett Quigley (Boston, Mass.): Dr. Medl asked for suggestions about controlling pressure necrosis in wounds involving transplantation of skin.

A properly placed Kirschner wire through the distal tibia or distal femur and suspension of the limb will solve a great many problems and has the added virtue of providing elevation. I have used this often enough to recommend it with confidence.

Alfred Wells Farmer (Toronto, Can.): Dr. Medl was kind enough to send me his paper and ask me to discuss it, but practically everything I was going to say has already been said.

I think the main feature is that while we may all know about these conditions ourselves, the younger generation probably does not; yet cases of acute trauma very often are admitted to their care. In the operating room their subconscious whispers to them saying, "I wonder whether that flap will live or not," and a well-wishing visitor may be saying the same thing.

They are somewhat afraid to cut off a flap even if they are quite sure that the circulation will not be adequate to maintain it for the next few days. Our advice has been to err continually on the side of cutting it off—cutting off a little more rather than a little less.

I would like to congratulate Dr. Medl on his cases, and for showing also those in which he erred on the side of cutting off less and not cutting off any of the flap at all.

In regard to Dr. Stark's presentation, I would agree with Dr. White that we also tend to use thigh-to-leg flaps, particularly in children. I notice one of his cases was a child in whom he used a cross-leg flap for a foot on the opposite side. We would not do that but would use a thigh-foot flap. We tend to leave the leg alone if possible. The patient has a long distance to go throughout life, and circulatory troubles affect legs far more often than thighs.

In contradistinction to Dr. White, we use a posterior thigh flap in practically all cases; it is easier to look after. It may be fashioned as a very large flap, and done without any initial preparation.

One other word about Dr. Medl's presentation. I think the removal and replacement technique can be carried a little too far on occasion. There are times when it would be far better to use an immediate flap replacement, a large jump flap or something like that, instead of replacing the original skin. The original skin should be taken off and used for backing the pedicle flap.

James F. Connell, Jr. (closing): I would like to reiterate that the measures in the conception of wound healing that I brought to the fore have a long way to go before they are fully established as routine therapeutic agents. However, I will say that they are primarily used as ancillary measures to mechanical and surgical débridement. In most cases, though, we used the drug with the strictest test, i.e., allowing it to act alone on the substrate. This is the only way to test these agents basically.

Richard B. Stark (closing): Both Drs. White and Farmer have stressed the use of a cross-thigh rather than a cross-leg variety of flap. We have used the thighs as a donor site on many occasions, but these cases were largely in young, healthy, adult males of the type we saw in World War II, and in veterans from that war and the Korean conflict. Certainly the side by side position, with flexion of the knees at 45 degrees, is a far less taxing position for the older patient than the close-thigh flap. In many older persons we are attempting now to surface defects of the leg by using this particular pedicled attachment.

It has been stated in the literature on many occasions that the cross-extremity procedure is contraindicated in the older age group, which I take to mean those persons over forty. We are all seeing an older population with defective ower extremities; we are attempting to extend the usefulness of this procedure to this group of people.

Concerning the combination of the pedicle flap and the bone graft in one stage, I would say, Dr. White, that we certainly would not perform this unless subjected to a great deal of moral suasion.

Cuthbert in South Africa has recently reported on the use of this combined procedure for nonunion in nine cases. In five of these, primary union of the bone and success of the pedicle was obtained. In all cases the pedicle flap was successful, but the remaining four cases required an additional bone graft.

MICHAEL P. MANDARINO (closing): In presenting this paper, I hesitated to bring up any of the experimental features since I will present the experimental results of our work at the American College of Surgeons meeting in October, 1958.

As I said in the last point of my summary, extensive studies in metabolic route, toxicity, pathology and carcinogenicity are being pursued. We now have over 106 dogs, well over 100 guinea pigs, rats and even some burros. We have studied two human beings for two years with no untoward effects or negative results.

I would like to answer one of the questions which has been most frequently brought up. How does bone bridge the defect? Under a low powered microscope we have seen the yellow chemical and the bone growing right through it in a beautiful mosaic, with close approximation of both. I have seen no involucrum in our slides.

Under the high powered microscope, on the contrary, we have seen no involucrum but osteoblastic reaction. The chemical is yellow and the pink or bluish stain material contains the ostoblast which will deposit bone. This is one of our most gratifying features in all the experimentation, and has been proved time and time again in our studies on dogs.

WILLIAM T. MEDL (closing): In reply to the comments of Dr. Bell, the pitfall confronting the surgeon is that he sees a pink flap and does not recognize the degree of contusion. The progressively increasing edema, because of interference with venous and lymphatic drainage, slowly obliterates the arterial supply. It may take seven to ten days before necrosis is evident.

Dr. Quigley's suggestion is excellent. We were apparently too fearful of complications to use it but will try it in the future.

Pathogenesis of Post-traumatic Sympathetic Dystrophy

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PAIN in an extremity that develops following trauma, infection, thrombophlebitis and many other lesions has been recognized for years and designated by a variety of names. More than two centuries ago Pott, surgeon to St. Bartholomew's Hospital, described the pain which followed partial division of a peripheral nerve [1]. Denmark described an agonizing, burning pain in the arm of one of Wellington's troopers following an injury at the battle of Badajoz in 1812 [1]. Dissection of the amputated arm revealed a neuroma of the median nerve. Bell in 1812, Scarpa in 1832 and Hamilton in 1838 reported on patients with painful extremities following partial injury of nerves. In 1864 Paget wrote about the distressingly painful glossy fingers seen after injury to a nerve. He ascribed the abnormalities to impaired nutrition and circulation due to the nerve injury [2]. In the same year Mitchell, Morehouse and Keen [3], who were then stationed at a military hospital near Philadelphia, gave a classic description of a syndrome concerning pain produced by nerve wounds. Mitchell coined a term from the Greek to signify a burning pain: *kavoŕas* (burning) *αλγος* (pain) [4,5]. It is the consensus of contemporary authorities that the original clinical description of causalgia by Mitchell cannot be improved.

It was noted in time, however, that in many patients a painful extremity developed following trauma without demonstrable injury to a major nerve. In 1900 Sudeck [6] described acute atrophy of bone in the extremity which he ascribed to inflammation. The following year Kienbock [7] related acute atrophy of bone to antecedent trauma, but it was not until 1938 that Sudeck [8] accepted both inflammation and trauma as precursors of the osteoporosis that now bears his name. During the fifty-nine years that have elapsed since Sudeck's original paper many descriptions of post-traumatic painful extremities have appeared. Such terms as Sudeck's atrophy, Sudeck's syndrome, minor causalgia, causalgia-like state, post-traumatic painful osteoporosis, reflex dystrophy of the extremities, post-traumatic dystrophy and sympathetic dystrophy have been used to designate this syndrome. Both the clinical descriptions and the concepts regarding pathogenesis range over a broad area. This paper will attempt to harmonize the wide disparity of clinical descriptions and concepts of the pathogenesis of sympathetic dystrophy and also to present a neurophysiological basis for causalgic states.

DEFINITION OF TERMS

Definitions of terms are most important if one is to avoid confusion in the field of painful disorders. Causalgia, the term introduced by Mitchell, is defined as: (1) a burning type of pain not confined to the distribution of a peripheral nerve, which (2) occurs after trauma to a major nerve of an extremity and which (3) can be relieved by sympathetic interruption.

Sympathetic dystrophy is considered by us to be a causalgic state of an extremity relieved by sympathetic interruption. As pointed out by Holden [9], it differs anatomically from Mitchell's causalgia only in that there is no demonstrable injury to a major peripheral nerve. Finer points of distinction will be elaborated in the subsequent discussion.

Sudeck's atrophy refers to the characteristic

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osteoporosis that frequently occurs in causalgic states.

The clinical characteristics of post-traumatic sympathetic dystrophy observed in sixty-one patients at the University Hospitals of Cleveland during the past twenty years will be considered within these definitions. Patients who recovered spontaneously after a brief period of dystrophic pain have been omitted.

CLINICAL CHARACTERISTICS

Causes. Sympathetic dystrophy has many "causes" or precipitating agents. Reme [*10*] states that a recognizable cause always exists, whereas Schröter [*11*] reported five cases without antecedent injury in which the only trauma was excessive use of the hand. Becker [*12*] and Exner [*13*] found no discernible trauma preceding the onset of the syndrome in a few of their patients. The various causes that have been listed include: tuberculosis of fascia and bursae, infected wounds in the extremities, injuries to bone, freezing, burns, thrombophlebitis, lymphatic stasis, perivenous and intra-arterial injections, metastatic tumors, angina pectoris, myocardial infarction, mechanical trauma, operations, brain tumors, poliomyelitis, hemiplegias and arsenical polyneuritis [*10,13–18*].

The types of injury and the frequency of occurrence in sixty-one patients are listed in Table 1. Many authors have stressed the marked disparity between a relatively trivial initial injury and the subsequent severely debilitating causalgic state [*11,12,17,19–22*]. Several of our patients had had minor lacerations, uncomplicated fractures or small bruises. In five patients no definite history of antecedent injury was obtained.

TABLE 1
INJURIES THAT PRECEDED THE CAUSALGIC STATE IN SIXTY-ONE PATIENTS

Fracture	14
Sprain	11
Laceration	10
Trauma to soft tissues	10
Operation	3
Dislocation	1
Infection	1
Spinal anesthesia	1
Frostbite	3
Phlebitis	2
Unknown	5

Fractures. The role of fractures in the development of sympathetic dystrophy and the occurrence of osteoporosis has probably been overemphasized. This is reasonable when one considers that the original description of Sudeck [*6*] focused attention on post-traumatic osteoporosis. Also, when changes do occur in bone, they can be recorded objectively by x-ray film and studied histologically. The fact that pain, the one clincial criterion of the syndrome that is always present by definition, cannot be recorded objectively or studied readily, has undoubtedly contributed to the preoccupation with fractures and post-traumatic changes in bone.

An important point to recognize is that both sympathetic dystrophy and Sudeck's atrophy as defined may be caused by many types of trauma other than fracture [*9,14,15,24–26*]. Only fourteen of our sixty-one patients with sympathetic dystrophy (23 per cent) had a fracture as the initial injury.

There is, however, an appreciable incidence of sympathetic dystrophy following fractures [*15*]. Zehntner [*27*] found seventy-five patients among 678 with fractures (11.6 per cent) and Bierling [*28*] found 570 patients among 3,170 with fractures (18 per cent).

Causalgic states frequently occur without osteoporosis. In this series only nineteen patients (31 per cent) had radiographic changes. Hermann and co-workers [*19*], however, reported an incidence of 50 per cent. Of our nineteen patients with osteoporosis, only eight had antecedent fractures.

Stages. Most authors have classified patients into several groups [*10–12,14,15,17–19,27,29–33*]. The basis for the division has usually been objective radiographic and clinical signs rather than subjective pain. Although there is lack of uniformity in the classification, it is apparent that the causalgic state is a dynamic disease with frequent simultaneous involvement of skin, muscle, blood vessels and bones. There is only one denominator common to all stages and for all patients and this is *pain* in the extremity. All other changes may or may not occur [*18*].

In stage 1 pain may start immediately or not until several weeks after injury. There may be an increase in dermal blood flow, hyperthermia, edema, increased growth of hair, increased longitudinal nail growth, hyperhidrosis and wasting of the muscles with the onset of pain. The pain in the extremity is burning or aching

TABLE II
DESCRIPTION OF SIXTY-ONE PATIENTS WITH CAUSALGIC STATES

Age (yr.)	
20–29	15
30–39	9
40–49	15
50–59	14
60–over	8
Race	
Caucasian	58
Negro	3
Sex	
Male	23
Female	38
Extremity Affected	
Upper	29
Lower	32

in character and is constant. It is made worse by movement, emotion, and auditory and visual stimuli. It is out of all proportion to the severity of the antecedent injury. The pain is usually lessened in a quiet environment, by sleep and by narcosis. There may be no radiographic changes in the first or acute stage until four to eight weeks following the onset of pain [*17,25,30*].

Stage II develops in about three months [*12*]. In this dystrophic stage the skin is cool, pale, gray and frequently cyanotic. The edema changes from a soft to a brawny type with glazed overlying skin. The hair becomes scant. The nails become brittle and crack and have heavy grooves. The pain persists and motion is very restricted. X-ray films reveal diffuse rarefaction of bone, especially in the epiphyseal region.

Stage III, or the atrophic stage, is generally considered irreversible with extensive structural changes. There are decreased dermal blood flow, atrophic skin, decreased fat pads in the fingers and pointed fingertips. The growth of hair and nails and formation of sweat may again be normal [*15*]. Bones may show marked decalcification with fixed articular rigidity. In this stage the pain has frequently spread proximally in the limb and has become intractable [*17*].

Race, Age, Sex and Extremity Involved. The distribution of the sixty-one patients by race, age, sex and extremity involved is listed in Table II. The predominance of Caucasian patients does not reflect the racial distribution of patients admitted to the University Hospitals and probably is therefore a significant finding. Bierling and Reisch [*28*] reported the highest incidence of postfracture Sudeck's syndrome in patients under twenty-five years of age and over sixty, whereas Reichle [*15*] found Sudeck's syndrome most frequently in women between forty and sixty years of age. Plewes [*30*] found an average age of fifty-eight, with the distribution of thirty-three to seventy-six years. Reichle [*15*], Bierling [*28*] and Plewes [*30*] agree with our finding of a higher frequency in women. Bierling found Sudeck's syndrome two times as frequent in the lower extremity, and he ascribed this to the slight predisposition of the lower extremity to circulatory congestion [*28*]. Exner in agreement with others found a higher incidence in the upper extremity [*13,17, 34*]. He ascribed this to a higher vulnerability of sympathetic nerves in the cervical area. Our observations do not indicate a predominant extremity.

DIFFERENTIAL DIAGNOSIS

Many clinical states of pain have been excluded by definition. Since the clinical manifestations may be highly variable depending upon the individual and the time elapsed since the injury, there are many clinical entities with which it may be confused. Hartley [*17*] lists the following: tenosynovitis, lymphedema, atrophy of disuse, senile or postmenopausal osteoporosis, tuberculous or pyogenic osteomyelitis, peripheral neuritis and radiculitis, peripheral vascular diseases which manifest severe pain such as occlusions and thromboangiitis obliterans, radiological changes in bone after repeated hemarthroses of hemophilia, traumatic hysteria and rheumatoid arthritis.

The vascular disorders can be differentiated on the basis of physical findings. They usually have a more extensive involvement including other extremities. An antecedent history of trauma is an exception in vascular diseases, whereas it is usually present with sympathetic dystrophy. If the definition of sympathetic dystrophy is strictly followed, differential diagnosis is relatively uncomplicated.

The dominant symptoms in our cases are listed in Table III.

TABLE III
DOMINANT SYMPTOMS IN SIXTY-ONE PATIENTS WITH CAUSALGIC STATES

Pain*	52
Swelling	15
Hypersensitivity to cold	14
Cold	8
Stiffness	8
Paresthesias	6
Increased perspiration	4
Discoloration	3
Numbness	3
Trigger areas	3

* Pain was present in all but was not the chief complaint in 9 patients.

PATHOGENESIS

Bone. A mechanism that is responsible for causalgic states has remained obscure. Although the original descriptions of Mitchell emphasized pain as a characteristic symptom, the close relationship of causalgia to post-traumatic dystrophy was not appreciated for many years. The early descriptions of Sudeck referred to bone changes, and the early concepts of pathogenesis were oriented toward the osseous rather than the sensory changes. Initially Sudeck [*6*] thought osteoporosis was the direct result of inflammation, whereas Kienbock [*7*] related it to trauma. Many years later Sudeck [*8*] redefined the syndrome in terms of bone atrophy. He described three types of post-traumatic atrophy: Acute atrophy was considered to be a normal physiological sequence of a severe injury to a limb; chronic atrophy was considered a consequence of delayed healing of the primary injury, particularly fractures; chronic traumatic dystrophy was thought to follow apparently insignificant injuries [*20*]. Many authors supported the concept that the bone changes in Sudeck's atrophy represent an aberration of normal healing, a "running off the track" of the usual reaction of regeneration after fractures [*10,17,35*], but Blumensaat [*24*] has objected to this interpretation. For many years Watson-Jones [*36*] considered the bone changes simply as atrophy of disuse but later he ascribed them to the generalized non-specific response to stress. Some authors continue to regard the bone changes as atrophy of disuse [*17,21,25*], while others have defended the idea that Sudeck's atrophy has characteristic bone changes [*19,30,37*]. There are many cases of sympathetic dystrophy, however, in which there is no bone change. It is unlikely therefore that the osteoporosis is a cause of the syndrome. Whether the abnormalities in bone are characteristic or simply a reflection of disuse resulting from painful extremity remains to be settled.

Blood Flow. Attention was directed to the autonomic nervous system early because interruption of the sympathetic efferent impulses either temporarily or permanently was found to be very effective in treating patients with causalgic stages. For many years the theory was advanced that the pain and dystrophic changes were a result of altered peripheral blood flow due to sympathetic activity [*17,26,29,32,38–40*]. Peripheral circulatory studies were performed by plethysmography, oscillometry, reactions to histamine injections, dermatherm readings, capillary microscopy and fluorescein injections [*17,25,30,41,42*]. Many instances of increased blood flow in the involved limb were recorded. On the other hand, both Holden [*9*] and Mayfield [*43*] demonstrated that patients may have increased, normal or decreased blood flow. Doupe, Cullen and Chance [*18*] and Nathan [*75*] discounted vascular changes as the cause of pain because the production of vasodilation by means other than sympathectomy did not relieve the pain. Capillary constriction was ruled out because they were unable to stop the pain by the method of suprasystolic compression of the limb which deTakats suggested should stop pain of causalgia [*18*]. It is difficult to conclude in view of these observations that alterations of total blood flow are concerned etiologically with the pain of causalgic states.

An alteration in hemodynamics may, however, account for the bone changes [*26,39,44*]. Meyer demonstrated in 1853 that rapidly developing osteoporosis is associated with hyperemia in the bone [*25*]. Gurd [*44*] has evidence that the hyperemia leads to decalcification of bone whereas blood supply causes an increased deposition of calcium in bone. He postulated that persistent hyperemia is produced in an injured limb because of repeated or continued irritation at the site of fracture or injury. The surrounding tendons and ligaments also undergo marked regressive changes with hyperemia. Although Hartley [*17*] agrees that hyperemia may produce the deossification, he points out the paradox that deossification

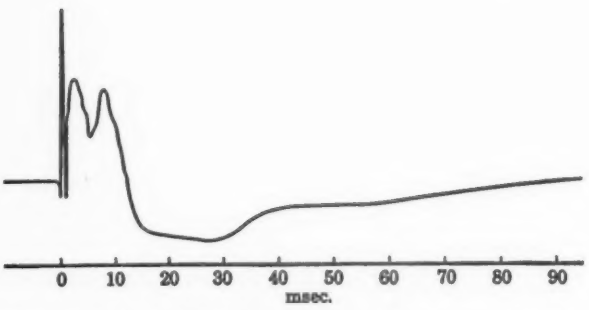

FIG. 1. Spinal cord potential resulting from a single induction shock applied to a dorsal root. Prolonged negative and positive potential indicates internuncial neuron activity. (From: ERLANGER, J. and GASSER, H. S. Electrical Signs of Nervous Activity. Philadelphia, 1937. University of Pennsylvania Press [47].)

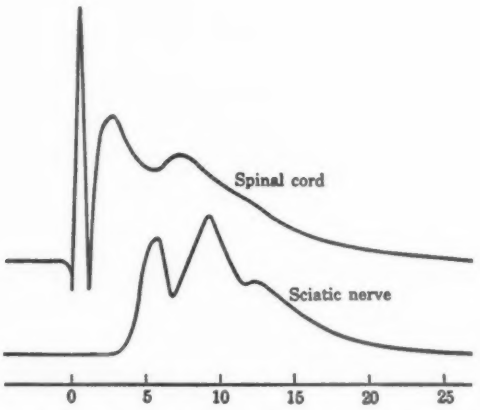

FIG. 2. Comparison of the duration of the discharge of motor impulses into the sciatic nerve with the duration of the negative part of the potential evoked in the internuncial neurons of the spinal cord by a single afferent volley from a dorsal root. The experiment was performed on a cat under light ether anesthesia. (From: ERLANGER, J. and GASSER, H. S. Electrical Signs of Nervous Activity. Philadelphia, 1937. University of Pennsylvania Press [47].)

persists in late stages of the syndrome when marked vasospasm is frequently present. A satisfactory correlation remains to be established in cases of sympathetic dystrophy between osteoporosis and decreased blood flow.

Metabolism. There have been sporadic attempts to relate metabolic alterations to activity in the autonomic nervous system and production of Sudeck's syndrome [*15*]. Dohrmann [*45*] found no elevation in alkaline phosphatase after fractures in eight patients with Sudeck's syndrome. He considered this a result of poor osteoblastic activity. Sieber [*38*] found that an arrest of creatine excretion may be a sign of recovery from the acute stage. Patients with a fixed nervous abnormality and histological changes of degeneration were found to have a decreased oxygen consumption. Buchberger [*40*] considered sympathetic dystrophy a sequel of poor circulation which impaired removal of metabolic products which in turn increased vasospasm. Miller and deTakats [*25*] found that acidosis and Prostigmine® aggravated the pain of Sudeck's atrophy. They postulated that excitation of efferent vasodilators led to the production of a substance in the peripheral end organs which caused both vasodilation and pain. To date there is insufficient evidence to suggest a particular metabolic defect as the cause of sympathetic dystrophy. It seems more reasonable to regard the metabolic changes that have been described in the same light as the changes in bone and blood vessels, namely, as a result rather than a cause of the syndrome.

The Vicious Circle of Reflexes. The problem that faces one who attempts to explain the pathogenesis of sympathetic dystrophy is how a trivial injury can produce pain which far surpasses that of the initial injury and which persists long after the injury has healed. Livingston [*46*] postulated that three factors are involved in establishing a vicious circle of reflexes. The initial factor is trauma and tissue damage resulting in chronic irritation of a peripheral sensory nerve. In some instances there is a demonstrable injury to a small sensory nerve, but frequently no damage can be found or even inferred on the basis of the trivial injury. The chronic peripheral nerve irritation produces an increased number of afferent impulses to the spinal cord. The exact local mechanism—whether biochemical, enzymatic or bioelectrical—has not been established.

Livingston's second factor proposes an abnormal state of activity in the internuncial neuron center produced by the increased afferent impulses. Erlanger and Gasser [*47*] have shown that a single afferent stimulus produces a relatively prolonged effect on the activity of the anterior horn cells. (Fig. 1.) For example, a single afferent stimulus of 2 milliseconds' duration to a dorsal root will produce a discharge of impulses from the anterior horn which persists for 20 milliseconds or longer. (Fig. 2.) The intracord burst of activity occurs in the internuncial pool. An increased activity in the internuncial pool may lead to Livingston's third factor, i.e., a continuous and increased stimulation of efferent motor and

sympathetic neurons. This results in various responses in the periphery. Livingston believed that interruption of the vicious circle either at the source of injury or in the efferent portion of the circle may be curative, but it remained for subsequent investigations to explain how this may be effective.

Hering demonstrated in 1882 that fiber interaction may occur at an injured region in the sciatic nerve of a frog. The injured region served as an artificial synapse (ephapse) [*48*]. In 1942 Katz and Schmitt [*49*] showed that electrical stimulation of isolated nerve fibers augments the excitability of adjacent nerve fibers. Two years later Granit, Leskell and Skoglund [*48*] presented direct experimental proof of cross stimulation in a mixed nerve between motor and sensory fibers at a point of nerve injury. They showed by means of a cathode ray oscillograph that stimulation of a motor root caused an afferent discharge through the sensory root only when the peripheral mixed nerve was injured. The injury could be produced by simple ligation of the nerve. In the absence of injury no afferent discharge was noted.

Doupe, Cullen and Chance [*18*] presented a theoretical concept of causalgic pain based primarily on these experimental observations. They postulated that as a result of an "artificial synapse" in a partially damaged peripheral nerve, efferent sympathetic impulses produced painful afferent impulses via somatic fibers. This concept of artificial synapse (ephapse) might be considered a fourth factor to complete the vicious circle originally proposed by Livingston. It helps to explain why interruption of the efferent (sympathetic) portion of the circle may be curative.

The theory of Doupe et al. assumes that activating impulses come from the sympathetic vasomotor, pilomotor and sudomotor discharge, augmented by temperature changes and emotion. They ascribed the peculiar qualities of causalgic pain to direct cross stimulation of sensory fibers by efferent sympathetic impulses at the point where the nerve is injured. They furnish an explanation not only for the increase in pain which takes place with temperature changes, but also for the peculiar exacerbations during any form of emotional excitement or in some instances resulting from the everyday visual and auditory stimuli. Since causalgic pain is reduced in a quiet, stable environment and during sleep when the tonic hypothalamic discharge is greatly diminished, this seems reasonable.

Walker and Nulsen [*50*] have given striking evidence that causalgic pain is produced by sympathetic stimulation only when a nerve injury is present. These authors while performing thoracic sympathectomies applied pull-out electrodes to the decentralized upper thoracic sympathetic ganglia. The electrodes were stimulated forty-eight hours to eight days after the preganglionic sympathectomies. In the majority of fully conscious patients who had not had causalgic pain, stimulation of the electrodes produced sensations referred to the local area in the back or to the distribution of the second and third intercostal nerves. In three patients who had suffered from causalgia, however, pain was referred to the arm and hand. In these three patients a characteristic and reproducible pattern of response was shown. The response of pain was delayed after a stimulus for a latent period of four to twenty seconds. In two patients the subjective complaints were closely paralleled in time by a visible pilomotor response over the entire arm and shoulder. This appeared a few seconds before discomfort was noted and faded away simultaneously with the pain. There was often a low grade aching in the arm or hand for as long as twenty-four hours after stimuli were applied.

The findings of Walker and Nulsen therefore add clinical evidence to the proposal of Doupe et al. that the pain in dystrophies is due to sympathetic efferent cross stimulation of sensory fibers. Indirect evidence for exacerbation of pain by sympathetic overactivity has been emphasized by Spurling [*51*], whose patient with causalgia was relieved for a number of hours after a chill produced by typhoid vaccine. It is of interest that durring the chill period, when the vasoconstrictor and pilomotor activity was increased, the pain was greatly intensified. During the stage of defervescence sympathetic activity was decreased and pain was temporarily relieved.

Steinbrocher, Spitzer and Friedman [*76*] have studied a variety of seemingly unrelated clinical disorders such as causalgia, reflex traumatic dystrophies, painful disability of the shoulder following coronary occlusion, hemiplegia, idiopathic shoulder-hand syndrome and other conditions that afflict the upper extremities. They concluded that many different states can result in reflex vasomotor disturbance, pain, muscle

spasm and atrophy in the upper extremities. The physiologic mechanisms in the separate entities may be closely related, if not identical, with afferent stimuli mediated through the internuncial pool to efferent sympathetic fibers. The reflex was thought to be provoked and maintained by the precipitating condition regardless of etiology. The possibility of an ephapse was not considered because, unlike causalgic states, the initiating disturbance was not a peripheral injury. Their concept of a common pathogenesis was strengthened since treatment by sympathetic interruption was effective in many of the states they described.

Tinel [52] and Doupe [18] found some instances in which clear-cut relief of pain could be produced by procaine injections distal to the site of injury. At first glance this would seem to argue against the theory of the vicious circle of reflexes. To explain this phenomenon it must be remembered that peripheral nerve endings are constantly discharging impulses even in the resting state. Pain thresholds may be reached when these impulses are summated or augmented by efferent impulses which cross over at the site of nerve injury. In those cases in which a block distal to the site of injury relieves pain it is possible that the cross-over sympathetic efferent impulses are not of themselves sufficiently intense to produce pain but require summation with the normally ascending somatic impulses.

The pain of sympathetic dystrophy is rarely confined to the peripheral distribution of a sensory nerve but is widespread in the extremity. Patients have been observed with an injury to an index finger which leads to diffuse pain involving the entire hand and forearm. This discrepancy between the small area of injury and the wide area of pain may be explained by augmentation of small fiber impulses in the internuncial pool which produce an increased number of stimuli to the hypothalamus and cortex. Although the pain originated in a small area and can frequently be relieved by a procaine injection into the area, the cortex interprets the pain as originating from a much wider area due to the summation of impulses from the internuncial pool. Also, as Nathan [75] points out, the pain resulting from impulses from an ephapse are referred by the patient to the entire area of distribution of that sensory nerve.

Dorsal Root Efferent Reflex. Gotch and Horsley in 1891 described efferent reflex discharges over the dorsal root of cats [25]. Toennies [53] showed that stimulation of a sensory nerve in a cat will activate a spinal center to discharge a portion of its energy backward down posterior roots as well as forward down the efferent fibers of anterior roots. He calculated that at least 35 per cent of the alpha fibers in the saphenous nerve are accessible to reflex activation. Lewis [54] termed the efferent dorsal root nerves nocifensor and said they caused a change in cell permeability with the release of a material that leads to itching, hyperalgesia and vasodilatation. Bishop, Heinbecker and O'Leary [55] also described efferent fibers in the dorsal root which they considered to be parasympathetic and responsible for vasodilatation. It is unlikely that an efferent reflex over the dorsal root can explain the pathogenesis of sympathetic dystrophy, because vasodilatation is not necessarily a constant feature of the syndrome. Also, if pain were due to a dorsal root reflex, it would be hard to understand the relief obtained by sympathetic interruption. If the dorsal root reflex does exist in man, it may contribute to vasodilatation through increased excitation from the internuncial pool.

Sympathetic Afferents. The role of the sympathetic nervous system in pain conduction has been studied for several years. Davis and Pollock [56] stimulated the superior cervical ganglion in lightly anesthetized cats and produced reactions which they interpreted as being due to pain. Others have studied the effect of stimulation of the sympathetics in man [50, 57–59]. Both mechanical and electrical stimulation of the central sympathetic trunks produces pain of a burning and gripping character which is not well localized. Threadgill [60] claimed that he found impulses enter the spinal cord through the lumbar sympathetic chains from the lower extremities, but Holden [9] has not been able to confirm this. Leriche [61] maintained for many years that peripheral afferent impulses may be transmitted via sympathetic pathways as they are in the splanchnic system. Part of his reasoning was based on the observation that pressure on a femoral artery in a patient under spinal anesthesia will produce pain. DeTakats [25], however, found that arterial puncture in a sympathectomized limb is also painful. A series of experiments by Moore and Singleton [62] lead to the convincing conclusion that all painful impulses from the extremities pass through somatic nerves.

Afferent fibers from the extremities have been studied recently by Collins and Randt [*63*]. They have been able to trace the small unmyelinated C fibers from the periphery to the medulla and up into the mid-brain. The electrial response of the spinal cord, medulla and mid-brain is more prolonged and of greater amplitude following stimulation of C fibers than after stimulation of the larger somatic pain fibers.

It is to be noted that the final efferent sympathetic fibers are also unmyelinated C fibers. Their morphological similarity to afferent C fibers leads one to postulate a physiological similarity, although by the definition of many neurophysiologists the peripheral sympathetic nervous system does not contain afferent fibers. The ability of the afferent C fibers to alter the central excitatory state of the nervous system and thereby stimulate the sympathetic efferent system appears to support the postulate of a functional relationship between the afferent C fibers and the terminal efferent sympathetic C fibers. Certainly the work of Foerster and others leaves little doubt that stimulation of the sympathetic system in man causes pain [*50,57–59*]. It seems reasonable to us that the pain in both causalgia and causalgic states is transmitted by both somatic nerves and the omnipresent small unmyelinated afferent C fibers. It is, in part, the increased activity of C fibers that leads to intense activity of the internuncial pool. It is the activity of the larger pain fibers that contributes to the localization of pain in an extremity.

The Role of the Psyche. There is a difference between causalgia and the causalgic states that may explain some of the differences in clinical behavior despite a similar pathogenesis for the two states. Reichle [*15*] considered that patients who have Sudeck's atrophy are of an unstable, hysterical type. Exner [*13*] and Baur [*64*] proposed that a constitutional lability of the sympathetic nervous system predisposes patients to causalgic states. Marti [*32*] believed there is an increased incidence with psychopathies and vegetative lability. Bierling [*28*] opposed the theory of endogenous predisposition because he found a greater severity of causalgic states in people with bilateral fractures than in those with simple fractures. Most authors, however, stress a lack of relationship between the initial trauma and the incidence or the severity of causalgic conditions.

Causalgia, in contrast to sympathetic dystrophy, does not seem to occur because of a constitutional predisposition. The personality changes found during the painful state are thought to be secondary to the pain. Psychiatric tests performed on Mayfield's patients with injuries to major peripheral nerves demonstrated that personality changes disappeared following relief of the causalgic pain [*43*].

TABLE IV
THERAPEUTIC PROCEDURE PERFORMED UPON SIXTY-ONE PATIENTS WITH CAUSALGIC STATES

Sympathectomy	31
Sympathetic block:	
Single	35
Multiple	5
Amputation	4
Excision of neuroma	3
Removal of foreign body	2
Physiotherapy	2
Immobilization	1
Spontaneous recovery	4

TREATMENT

There can be little question that many patients with mild post-traumatic causalgic states recover spontaneously or with the aid of very conservative measures. Many authors have emphasized the need for early conservative treatment with adequate immobilization of the site of the injury [*11,12,25,32,39*]. In our series of sixty-one patients, four did not require any specific therapy, one recovered following immobilization of an injured foot in a plaster cast and two recovered with the use of physiotherapy. (Table IV.)

Unfortunately, conservative measures do not succeed in many instances. Kiger [*65*] and others have warned against excessive delay in the application of more active therapy. He noted than many patients do not seem sick enough to force active therapy but that prolonged use of conservative measures results in a poor prognosis. The next phase of therapy usually employed is some form of sympathetic interruption. Several authors believe that repeated use of sympathetic blocks will cure most patients [*27,28,32,33,37,39,43,65–67*]. Eight of our patients were treated by a single block and five received multiple block therapy.

In 1916 Leriche [*61*] advocated periarterial sympathectomy as treatment for the causalgic state. As far as we have been able to find, the

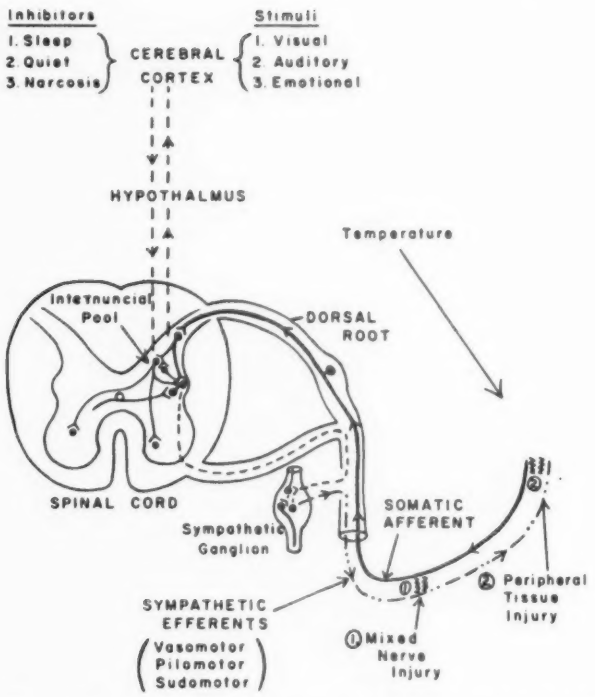

FIG. 3. Diagrammatic representation of factors involved in production of pain in causalgic states. Either mixed nerve (*1*) or peripheral tissue (*2*) injuries produce ephapse between sympathetic and somatic fibers, resulting in increased internuncial neuron pool activity. Since the neurons of the sympathetic system are closely allied to the internuncial pool, it is seen that repetitive stimulation may take place under proper conditions and the whole reflex chain could be self-reexciting. Inhibitory and stimulating factors known to be important in affecting pain of causalgic states are pictured.

first use of this form of therapy in the United States was employed by Heyman [*68*] for the treatment of a cold, swollen, tender foot and osteoporosis which had developed five months following a relatively minor injury to the foot. The response to periarterial sympathectomy was prompt and excellent. The patient walked within one week following surgery and was able to resume work in two months. Hermann and co-workers [*19,34*] reviewed eighty-four patients, thirty-four of whom were treated by periarterial sympathectomy with considerably better results than the remaining cases in which treatment was by conservative measures. They believed that periarterial sympathectomy was more effective than regional sympathectomy.

Today most authors regard regional sympathectomy as the treatment of choice in patients who have failed to respond to more conservative measures. All are in agreement that therapy should not be delayed because of the structural changes that occur in the extremity and the possibility that the pain may develop into an intractable central pain. The results of sympathectomy performed early are very gratifying. Only five of our thirty-one patients did not have a satisfactory response to sympathectomy. We ascribe the poor or fair results either to an inadequate operation, which is more likely to occur in thoracic sympathectomies, or to the personality of the patient which makes it difficult to evaluate the results of the operation. The history of two of these patients who did not receive benefit from the initial sympathectomy has been discussed in detail by Holden [*9*].

A review of the many adjuncts to therapy that have been employed illustrates the wide disparity in opinion regarding the pathogenesis of this disorder. Vasodilators have been tried on the assumption that the basic abnormality is an impaired blood flow. Some improvement has been reported [*12,17,26,40,69–71*]. Hartley [*17*] has resorted to amputation and we found that it was necessary to perform an amputation in four of our cases. Turner of Leningrad advised section of the dorsal interosseous nerve at the wrist, but Middleton [*26*] did not find this to be of value. Excision of a neuroma has been successful in removing the source of stimuli and thereby breaking the reflex chain in a few instances. This mode of therapy was successful in three of our patients. Other therapeutic measures have included the use of echinacin, a fresh vegetable extract [*72*], dilatol (phenyl-sec-butyl-nor-suprifen) [*27*], Padutin,® a sympatholytic drug [*70,71*], x-ray [*28*], hormones [*7, 17,21,28*], calcium-phosphorus compounds [*32*], intra-arterial oxygen [*13*] or procaine [*73*] and ultrasound [*24*]. Hartley [*17*] has emphasized the importance of adjunct therapy by a psychiatrist and the necessity of early settlement of compensation cases. If the pain complex extends to involve the entire organism, it may be necessary to resort to cordotomy or lobotomy with the likelihood of only fair results [*5*].

CONCLUSIONS

It is our belief that sympathetic dystrophy, a term used to include all causalgic states, is fundamentally the same condition as the causalgia described by Mitchell, Morehouse and Keen. The only significant difference between the two conditions is that causalgia is instigated by an injury to a mixed peripheral

nerve whereas sympathetic dystrophy has no such demonstrable injury.

Our concept of the pathogenesis of the causalgic state has been discussed with reference to pertinent neurophysiological experiments and is illustrated in Figure 3. Causalgic pain is started by an injury, either to a mixed nerve, most often the sciatic or median (point 1), or to many fine nerves in the periphery (point 2). The injury causes an increased number of afferent impulses transmitted by large somatic fibers and small unmyelinated C fibers. It also produces an ephapse so that efferent vasomotor, pilomotor and sudomotor small unmyelinated C fibers, which are part of the sympathetic nervous system, cause a cross stimulation of adjacent somatic afferent fibers.

The second link in the chain is increased activity in the internuncial neuron center produced by the augmented number of afferent impulses. Discharges from the internuncial pool go up the cord to produce an awareness of pain out of proportion to the severity of the injury and without regard to fine localization of the source of pain. They also stimulate anterolateral sympathetic efferent discharges. Cerebral and hypothalamic impulses may either inhibit or stimulate the internuncial pool activity. Noxious visual and auditory stimuli as well as increased emotional tension will accentuate the pain in causalgic states whereas sleep, a quiet stable environment and narcosis will ameliorate it.

The third link in the chain is activity of the efferent sympathetic nervous system which may produce a variety of dystrophic disturbances in the periphery as well as discharges across the ephapse to the afferent sensory system.

The fourth link which closes the chain is the ephapse produced by the initial injury. Normal or increased efferent sympathetic impulses are transmitted via the ephapse to augment or summate the afferent somatic impulses (points 1 and 2). An external environmental factor such as temperature may modify the sympathetic activity.

Interruption of the reflex chain at any of several points can and does relieve the pain in causalgic states. Local infiltration of trigger points in the periphery, somatic nerve blocks above and/or below a mixed nerve injury, and sympathetic blockade are all known to be effective in relieving pain.

Although this concept of pathogenesis is drawn from considerable experimental work, complete physiological proof for it remains to be established. For the present the pathogenesis, as described, may aid in understanding the many clinical features of causalgia and causalgic states and their response to current therapy.

SUMMARY

1. Sixty-one cases of sympathetic dystrophy are reviewed with reference to the wide disparity in clinical description and concepts of pathogenesis found in the literature. The only symptom found consistently is pain in the injured extremity.

2. Sympathetic dystrophy is considered to be fundamentally the same entity as causalgia. The only significant difference between them is that causalgia is initiated by an injury to a mixed peripheral nerve whereas in sympathetic dystrophy there may have been no such demonstrable injury. The term, Sudeck's atrophy, should be reserved to describe the osteoporosis occasionally found in causalgic states.

3. The pathogenesis of causalgia and causalgic states is represented as a vicious circle of reflexes under the modifying influence of hypothalamic and environmental factors. Pathogenesis is discussed with reference to pertinent neurophysiological experiments.

4. Causalgic pain which is unresponsive to a short trial of conservative measures should be treated by sympathetic denervation of the involved extremity. Failure to institute prompt therapy may result in intractable pain and irreversible structural changes.

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Fundamentals, Fads and Fallacies in the Carpal Tunnel Syndrome

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COMPRESSION of the median nerve in the carpal tunnel as a competent cause of focal atrophy, pain and sensory disturbances in the hand has been enthusiastically accepted by the medical community. The syndrome is characterized early by vague and fugitive complaints and occurs most frequently in middle-aged women who, may I add parenthetically, are possessed by other problems at that juncture. Subjective numbness and discomfort in the hand may offer very little in the way of specific insights in terms of treatment. The syndrome thus falls into the danger of too facile or perfunctory a diagnostic acceptance since the carpal tunnel syndrome makes an attractive hypothesis to explain many of these complaints. Under such circumstances, it seems to enjoy the popularity previously accorded the scalenus anticus syndrome as an explanation of so called brachialgia and vasomotor syndromes of the arm. Today, the scalenus anticus syndrome is rarely diagnosed and certainly rarely operated upon as a primary entity, and then only with the strictest of criteria.

TABLE I
POSSIBLE CAUSES OF "PSEUDOCARPAL" TUNNEL SYNDROMES

- Spinal cord lesions:
  - Syringomyelia
  - Tumors
  - Poliomyelitis
  - Amyotrophic lateral sclerosis
- Cervical root compression:
  - Disc
  - Spurring
- Brachial plexus compression:
  - Cervical ribs
  - Scalenus syndrome
  - Sulcal tumor
  - Outlet syndromes
  - Acroparesthesia
- Peripheral nerve lesions:
  - Traumatic neuritis
  - Neuropathies
  - Neurofibromas
  - Postmastectomy adhesions
- Musculotendinous lesions:
  - Tennis elbow
  - Bursitis
  - Tenosynovitis
- Musculoskeletal lesions:
  - Rheumatoid arthritis
- Muscular syndromes:
  - Dystrophies
  - Progressive muscular atrophy
- Anomalies of structure:
  - Absent muscles
  - Carpal variants
- Miscellaneous:
  - Glomic tumor
  - Minor causalgia
  - Acrodynia and Raynaud's phenomena
  - Collagen disorders
  - Coronary sclerosis

The present study consists of an attempt to review the neurological and neurosurgical concepts of the carpal tunnel syndrome along with personal observations on surgical treatment. In order to emphasize the hazards of diagnosis, Table I summarizes some of the lesions in which a primary diagnosis of carpal tunnel syndrome has previously been considered. It also offers a fairly complete summary of the lesions which must be considered in the differential diagnosis of pain in the hand coupled with sensory disturbances and atrophy.

Acroparesthesia is perhaps the most common entity to be confused with the carpal tunnel syndrome. Numbness and discomfort in the fingers, particularly with nocturnal accentuation, are the most frequent presenting complaints of the middle-aged woman. Taken lightly by many examiners, they are nonetheless most distressing symptoms of the menopausal age group. Careful study is ordinarily not very productive of information regarding the exact nature of the pathologic condition and the symptoms are generally accepted as fixtures of the menopausal syndrome. This is really only a manner of begging the question. The symptom complex is thought by some to be based on senescent changes in the thoracic outlet. These may consist in the laying down of adipose tissue in the plexus region and also in fibrotic changes in the connective tissue sheathing of the neuro-

FIG. 1. A simplified anatomic depiction of the course of the median nerve into the hand. The carpal tunnel zone does not reach beyond the branches to the thenar muscles.

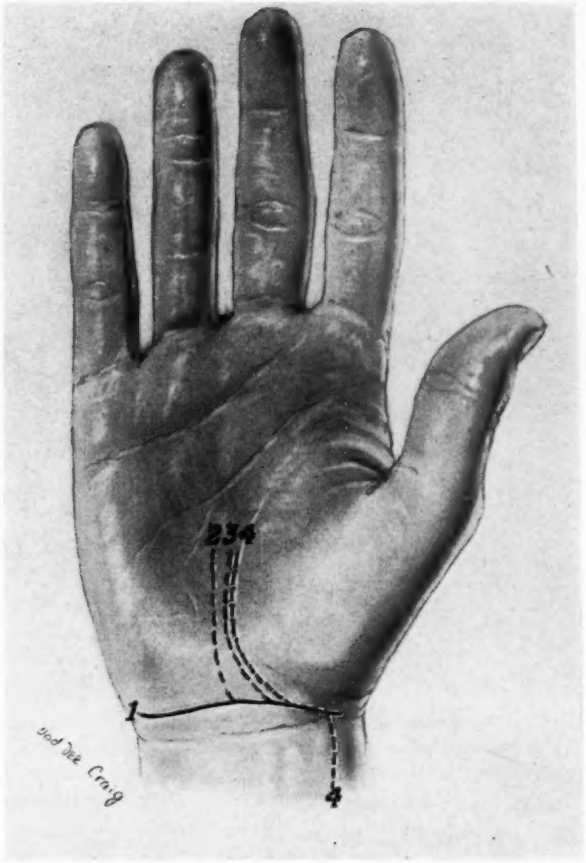

FIG. 2. A schema of the various incisions, other than straight vertical, for relieving compression of the median nerve in the carpal tunnel.

vascular bundle. Treatment is non-specific. Some relief usually follows the reassurance of the patient as to the benign nature of the complaint. Postural exercises to the shoulder girdle and attention to the dynamics of posture are occasionally helpful. At times, the symptoms may resemble those of the carpal tunnel syndrome and this similarity may be re-enforced by unconscious suggestion. Since the incidence of carpal tunnel syndrome is highest in women, particularly in the forty to sixty age group, acroparesthesia remains the most common problem in differential diagnosis.

The preponderance of women is striking, occurring in a 4 to 1 ratio in white people, and a 3 to 1 ratio in Negro people. The age peak hovers around fifty with the largest number of cases occurring in white housewives. Approximately 50 per cent of the cases seen in our clinic are of insidious onset and, therefore, the place of trauma deserves less emphasis than it is given. It is of interest that a solitary case has been reported from the Fracture Clinic of the Columbia Presbyterian Medical Center from among a thousand carefully followed fractures of the wrist. When occupation seems causally related to the onset of the syndrome, sewing, drill press operating, typing and piano playing stand out. The dominant hand is most frequently involved and roughly 10 per cent of the patients show an eventual bilateral involvement.

A special hazard worthy of emphasis lies in the surprising number of cases occurring in adult patients undergoing rehabilitation for chronic non-progressive neurovascular disorders. The increased stress involved in learning crutch and cane walking and the mechanics of self-care is apparently adequate for the production of the carpal tunnel syndrome. Careful observation of these patients is important since they are poorly prepared for further deficiencies in functional capacity.

FIG. 3. An example of the cosmetically excellent result in a successfully treated patient with bilateral involvement.

MODE OF TREATMENT

Non-surgical treatment has a very real place in the management of the carpal tunnel syndrome. Those patients with onset after acute trauma deserve especially long conservative treatment. In such instances there is obviously an inflammatory reaction with edema and possibly reversible local changes. The outlook is, therefore, quite favorable for relief by conservative means. This is equally true of cases of tendinitis or tenosynovitis due to unusual vocational or avocational stresses. Indeed, when there is any evidence of inflammatory reaction, the outlook is quite favorable with medical rather than surgical treatment.

Cases characterized by collagen or metabolic disorders are far better considered in terms of the general picture rather than the specific complaint of median nerve compression until such time as it is obvious that there will be no local response to adequate over-all treatment. The cases least likely to benefit from conservative treatment are those of insidious onset without any evidence of an acute or subacute inflammatory response.

CONSERVATIVE TREATMENT

Conservative treatment is well understood and need not be emphasized herein. It includes: (1) the avoidance and prevention of vigorous flexion and extension movements at the wrist. The use of a wrist support serves as a reminder rather than as an actual rigid fixation mechanism; (2) anti-inflammatory agents such as salicylates, Butazolidin® and adrenal cortical extracts; (3) conventional physiotherapy of various forms; and (4) x-ray therapy.

INDICATIONS FOR OPERATION

From a neurologist's standpoint, the prime indication for surgery lies in a specific neurological defect rather than a symptom complex. The following indications are observed in arriving at a decision for operation:

1. Muscle loss discretely in the realm of the median nerve is one indication. A progressive loss of muscle volume over a period of time will reinforce a decision for surgery. However, many non-specific entities may appear to show focal muscle loss. Just as senility is characterized by hollowing of the temples, there is a tendency to guttering of the thenar muscle group. This is particularly true in patients with arthritis, even without specific implication of the median nerve. Electromyograms and chronaxie studies are most helpful in establishing the focal and progressive nature of muscle loss.

2. Hyperpathia or dysesthesia—many patients have diffuse feelings of burning and tingling in the fingers, chiefly at night. This is a rather non-specific complaint. However, the patient with a clear-cut carpal tunnel syndrome in whom increasingly uncomfortable hyperpathia or dysesthesias of median nerve distribution develops should be considered for operation after a reasonable period of conservative treatment.

3. Some patients have a straight-forward sensory defect without much in the way of alteration in quality or the presence of established dysesthesia. Because of the functional importance of median sensibility, an impressive defect of increasing severity is a prime consideration in determining the course of therapy.

4. The presence of an obvious local inflammatory reaction in the tendons of the wrist in itself is not a sufficient indication for operation even when this is coupled with marked swelling. However, when the secondary neuritic signs are unresponsive to conservative treatment of all kinds, operation is advisable. As stated previously, however, these are patients who seem to respond best to conservative treatment and a vigorous trial should be carried out.

FIG. 4. An instance of straight vertical incisions bilaterally with a poor cosmetic result and uncomfortable scars.

FIG. 5. Contrasting result with transverse wrist approach and straight vertical incision. The latter procedure was followed by recurrent symptoms due to overlying scar formation.

5. True interference with vocational efficiency is an adequate indication for operation as with any non-mortal type of surgical condition. The pianist or engraver who gets relief on rest with return of complaints as soon as he returns to his vocation deserves operation as soon as this becomes obvious.

When is surgery specifically contraindicated? An operation should be avoided in the presence of multicentric foci of similar complaints such as calcific tendinitis in the shoulders, tennis elbow, cervical arthritis and gout. These, along with the less common intrinsic metabolic defects, should be thought of as in a totally different category in terms of the philosophy of treatment. The chief burden of attention should be focused on the primary pathologic condition since these disorders tend to do poorly after local procedures. This is likewise true of the more esoteric entities such as amyloid neuritis. The patient with rheumatoid arthritis should be operated upon only when his medical counsellor believes that the local handicap completely fails to respond to general treatment and grossly interferes with function.

OPERATIVE PROCEDURES

One has a choice of various surgical approaches for the decompression of the carpal tunnel. It should be remembered that by definition the syndrome consists in compression of the median nerve as it courses through the wrist and into the palm of the hand to just beyond the motor branches to the thenar muscles. (Fig. 1.) Extensive surgery of the hand and forearm is not necessary for the decompression of the nerve in this specific area. This point is emphasized because in many clinics the approach is through a quite radical exploration of the palm and forearm. It is one of the purposes of this paper to point out some of the dangers of such an approach. It is impossible to make any dogmatic statement about the type of incision needed in an individual case. However, a routine radical exploration of the entire wrist zone into the mid-palm, through any of the conventional incisions, is usually unnecessary and can be mutilative in terms of restoration of normal function and the prevention of complication.

Although the choice of incision depends completely on the nature of the individual problem, the simple transverse incision in the fold of the wrist deserves consideration as the fundamental surgical approach when there are no complicating factors. (Fig. 2.) It is cosmetically sound and ordinarily allows easy access to the nerve throughout its course within the area designated. Most important, it is the incision least likely to cause future discomfort from scar formation. One need not go into detail about the various incisions which are commonly used except to derogate the use of a simple vertical incision into the palm from the wrist. It has been by no means discarded.

Since the majority of our cases are of insidious onset, without evidence of acute tenosynovitis or abnormality of orthopedic structure, the simple horizontal or transverse incision in the fold of the wrist is commonly used and appears to be adequate. (Fig. 3.) It is a simple approach and allows a rapid and adequate exposure of the nerve and the overlying

structures as far as is necessary into the palm. Although emphasis has been placed on potential damage to the nearby artery in this incision, we have as yet seen no such complication. We have never seen fit to use a tourniquet or Esmarch bandage. With a simple wrist incision, bleeding is never of moment and is usually controlled by a preliminary injection of local anesthetic into the local tissues. Since the sole object of the operation is decompression of the nerve in the carpal tunnel, we try to avoid disturbing the nerve in its bed of areolar tissue. Indeed, we believe that it is important to manipulate the nerve as little as possible and in so doing prevent damage to its blood supply and the formation of fibrous adhesions. Likewise, when there is no obvious space-occupying pathologic condition of the tendons, we avoid manipulation or exploration of them. When there is an unusual collagen formation, a panniculus of granulation tissue or cystic collections in the tendon sheath, naturally the approach is different. However, we continue to emphasize the principle of avoiding unnecessary handling and exploration of structures which are not directly involved in the compressive syndrome. Under such circumstances, the operative procedure is rarely of longer duration then twenty minutes. The wounds heal strikingly well and the cosmetic result leaves very little to be desired. We have had no instances of recurrence of symptoms in our series.

DANGERS OF VERTICAL INCISIONS

We have never seen the formation of keloid or uncomfortable scars in patients with a transverse wrist incision. However, the straight vertical incision carries a distressingly high incidence of such complications. (Fig. 4.) In two cases we have seen the recurrence of compression of the median nerve due to keloid formation in the palm. Individuals who must hold instruments vocationally and those who use supports are particularly bitter about the discomfort and pain from palm and wrist scars. Such complaints have re-enforced us in our belief that the transverse incision should be used wherever possible. From our individual observation, we believe that the complications of what might be called the radical exploration are far more prevalent than those related to the transverse incision. The recurrence rate for the vertical incision is higher. When there is a tendency to keloid formation this is particularly true. It is of interest that the six cases of keloid formation which we have seen occurred in white patients. It would seem particularly worth while to avoid a keloid-forming incision in the Negro patient for fear of a recurrence of symptoms due to direct compression of the nerve. Figure 5 illustrates both types of incision in a single individual. Among other things it serves to demonstrate that scar response is not inherent in the patient's background. This person had a florid recurrence of all her previous symptoms and was treated by x-ray therapy.

CONCLUSIONS

1. The carpal tunnel syndrome must be dignified by careful diagnostic work-up of the patient because of the wide range of differential possibilities.

2. A high incidence of insidious onset of the syndrome, along with the age group involved, suggests a background of senescent changes in connective tissue structures rather than actual trauma as a precipitating factor.

3. Those cases following obvious trauma respond more favorably to conservative treatment and deserve more vigorous attempts than those of insidious onset.

4. Where overt tendinous pathologic conditions are present, the problem should be approached from the standpoint of good hand surgery for successful treatment. This, naturally, includes the use of incisions calculated to afford access to all involved structures.

5. The established case with insidious onset and no obvious acute tendinitis can be dealt with most successfully through a simple incision. This approach avoids the danger of sequential complications such as keloid and discomfort in the use of the hand. Exhaustive exploration of the median nerve and the adjacent tendinous structures is generally unnecessary and occasionally meedlesome.

6. Individuals with the stigmas of collagen disorders, gouty diathesis, and myositic phenomena should be studied initially from an internal medical point of view rather than by direct surgical attack.

Injuries to the Hand from Homemade Rockets

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The purpose of this paper is not to present a new method of treatment, nor is it to chronicle a list of spectacular successes. Rather, we wish to bring to the fore and discuss an aspect of trauma to the hand which has only recently presented itself to any marked extent and which appears to be occurring with increasing frequency. It requires but little imagination to appreciate that the problem of injuries to the hand from homemade bombs or rockets is one that affects young people almost exclusively, the wisdom or timidity conferred by advancing years militating against the unnecessary exposure of life and limb in search of bigger and better bangs.

A consideration of a group of explosive injuries to the hands reveals that the average age of the victims involved is about fifteen years, and that almost half of these injuries result during the manufacture of homemade rockets and bombs. (Tables I and II.) The expenditure of more than a little ingenuity is necessary in the manufacture of these toys; and in fact the patients to be described herein represent a group of highly intelligent children, able with their hands and addicted to building and managing quite intricate instruments and tools. That this type of individual should be so severely handicapped is a matter of some concern, more so when one notes the association of injuries to the face, eyes and ears in a rather large number of cases.

Table I
Incidence of Injuries from Homemade Bombs and Rockets

Number of patients (all males)	42
Average age (yr.)	15
Number with associated injuries (including injuries to the face and eyes)	19

The characteristics of the damage ensuing to the injured member are well illustrated in Figures 1 and 2 (*left*). It will be readily appreciated that no matter how much skill and perseverance are expended in the management of such a case, the end result will often compare unfavorably with the intact organ. Consideration of the function of the intact organ guides the surgeon in planning his therapeutic program. Function is the cardinal aim and prehensility its most important expression. To this end the preservation of the thumb and an opponent is mandatory. Satisfactory manual

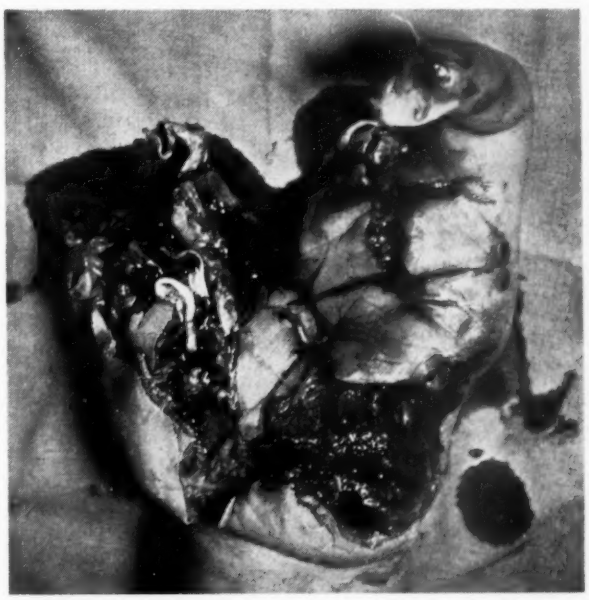

Fig. 1. Note the extensive soft tissue and bony destruction occurring as a result of explosion injury to this sixteen year old boy. The only digit left relatively intact was the index finger.

TABLE II

INJURIES FROM HOMEMADE BOMBS AND ROCKETS*

Date of Injury	Patient and Age (yr.)	Injury	Remarks
4/14/51	W. M., 16	Lacerations of hands and arms	Mixed powder in glass jars for magic act
4/14/51	J. H., 16	Lacerations of hands and arms	Mixed powder in glass jars for magic act
6/13/52	T. V., 13	Severe burns and lacerations of hands, face and chest	Made bomb in jar
6/13/52	A. S., 12	Severe burns and lacerations of hands, face and chest	Made bomb in jar
10/12/52	R. M.,	Burns and lacerations	Attempted to make firecrackers in laboratory
10/12/52	C. A., 15	Burns and lacerations	Attempted to make firecrackers in laboratory
3/30/53	17	Burns and lacerations of both hands and face	Made miniature rocket in glass container
3/30/53	C. P., 15	Lacerations of both hands	Made miniature rocket in glass container
4/5/53	J. S., 15	Loss of left thumb and index finger	Chemicals in test tube exploded
7/7/53	16	Lost left arm and left eye	Put fireworks powder in a souvenir grenade; died in hospital
4/12/54	C. M., 16	Lost portions of 3 fingers	Stuffed heads of matches in pipe and closed end to make a bomb
4/12/54	R. C., 16	Slight injuries	Stuffed heads of matches in pipe and closed end to make a bomb
4/12/54	J. H., 16	Slight injuries	Stuffed heads of matches in pipe and closed end to make a bomb
4/13/54	J. B., 15	Lost thumb and parts of 3 fingers of the left hand	Used match heads stuffed into pipe
7/13/55	J. E., 17	Lost left hand	Made bomb in glass
7/13/55	17	Injuries to hand	Made bomb in glass
7/13/55	16	Injuries to hand	Made bomb in glass
7/13/55	R. G., 15	All but destroyed hands and almost tore body in two	Died in hospital; made bomb in glass container
9/24/55	14	Burns of legs and hands; temporary impairment of vision	Pounded smoke bomb into pipe
9/24/55	16	Temporary impairment of vision	Pounded smoke bomb into pipe
9/24/55	13	Temporary impairment of vision	Pounded smoke bomb into pipe
10/4/55	T. F., 14	Lost 1 finger and parts of 3 others	Made bomb in basement; mother injured by shrapnel in arm

TABLE II (*Continued*)
INJURIES FROM HOMEMADE BOMBS AND ROCKETS*

Date of Injury	Patient and Age (yr.)	Injury	Remarks
10/4/55	J. M., 14	Lost parts of 3 fingers	Made bomb in basement
10/8/55	T. N., 13	Left thigh; severely injured	Explosive in pocket
11/12/55	16	Lost thumb and parts of fingers	Stuffed explosives into capsules
11/12/55	16	Severe burns of face	Stuffed explosives into capsules
10/9/57	P. G., 14	Lost left hand, shattered right forearm, wrist and little finger amputated	Made bomb in lead pipe
10/9/57	L. Z., 14	Severe injuries	Made bomb in lead pipe
12/18/57	L. L., 14	Fragments embedded in leg; multiple fractures of leg	Heated carbon dioxide cartridge and used it to propel toy
3/18/58	D. C., 16	Lost 4 fingers	Homemade bomb exploded; this boy had been burned 4 mo. previously and had been warned at that time to quit working with explosives
3/26/58	J. P., 14	Lacerations and burns of both hands and face	Homemade rocket filled with gunpowder exploded
3/26/58	E. G., 15	Lacerations and burns of both hands and face	Homemade rocket filled with gunpowder exploded
3/31/58	B. P., 15	Mangled left hand	Building rocket
4/12/58	C. H., 15	Fractured 3 fingers and thumb and lost distal joint of 2 fingers	Homemade rocket exploded
4/15/58	P. G., 14	Laceration of forehead	Touched off fuse of rocket he claimed he found; it contained metal warhead which struck him
5/3/58	F. C., 13	Lost 2 fingers and part of hand	Stuffed match heads into bomb tube and pounded it with hammer
5/3/58		Lacerations of left hand	Stuffed match heads into bomb tube and pounded it with hammer
7/24/58	G. R., 16	Burns of face and both hands; vision impaired	Rocket fuel exploded; this boy had been expelled from school 3 yr. before because of his fondness for explosives

* Note the increase in the incidence of this type of injury as evidenced by the appearance of eight cases in the first six months of 1958.

function implies a minimal level of sensory acuity. This, then, is our next important task, namely, the re-establishment of neural continuity.

Having satisfied the prerequisites of function, one must aim at providing as aesthetically an acceptable cosmetic result as is possible under difficult circumstances. (Figs. 1 and 2.) The primary procedure performed determines the final result, and so from the beginning an attempt must be made to visualize the final outcome of the therapeutic program. Although

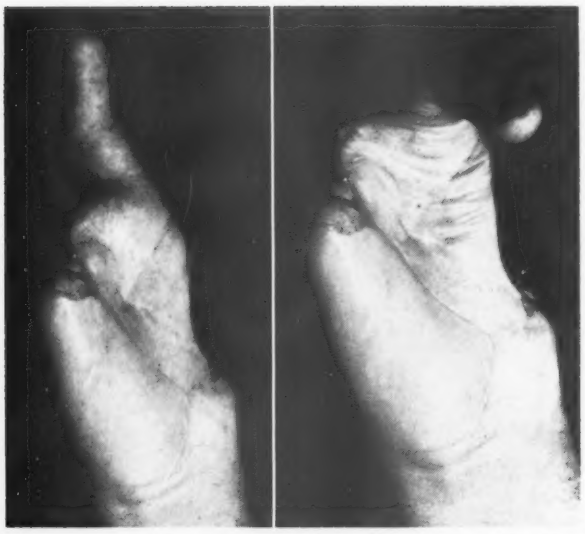

FIG. 2. Same case as Figure 1. *Left*, well healed final result with the index finger in active extension. *Right*, index finger in active flexion. This finger can be used actively in grasping and is of far more use to the patient than would be an inanimate hook.

devitalized tissue must be excised, great care should be taken to limit one's inroad into tissue that may prove of value in a later reconstructive procedure. Whereas one may be reasonably certain that a traumatized digit is going to prove a hindrance to future function, it is just as reasonable to preserve the member as a living tissue bank from which valuable skin may be removed and grafted to other less severely deformed but denuded digits.

Stress has already been laid on the necessity for maintaining the thumb intact. Nothing can replace even a portion of the first metacarpal, and no labor is too great that is directed toward saving such a remnant. (Fig. 3.) Almost equally important is the need for a thumb opponent, and the greater the destruction caused by the injury, the more vital the need for the preservation of the remaining digits.

Tendon repair as a primary procedure in the presence of these massively destructive injuries is hazardous. In selected cases primary repair of extensor tendons may be attempted. Internal fixation of bone using Kirschner wires, either lengthwise or as cross stabilizers, would seem to be the most satisfactory method of dealing with comminuted and open fractures almost always present in such cases, allowing as it does early active manipulation of uninjured or less severely injured digits. Nerves torn in association with loss of terminal portions of digits should be transected short of the final tip of the digit in order to prevent formation of painful terminal neuromas. Tendons, bones and joints should always be covered at the primary procedure. Lack of skin protection will result in a devitalized tendon within a period of twenty-four hours. Destruction and loss of tissue are severe in this type of injury, and may force the unwary into attempting closures of denuded areas necessitating tension. The already precarious blood supply of the

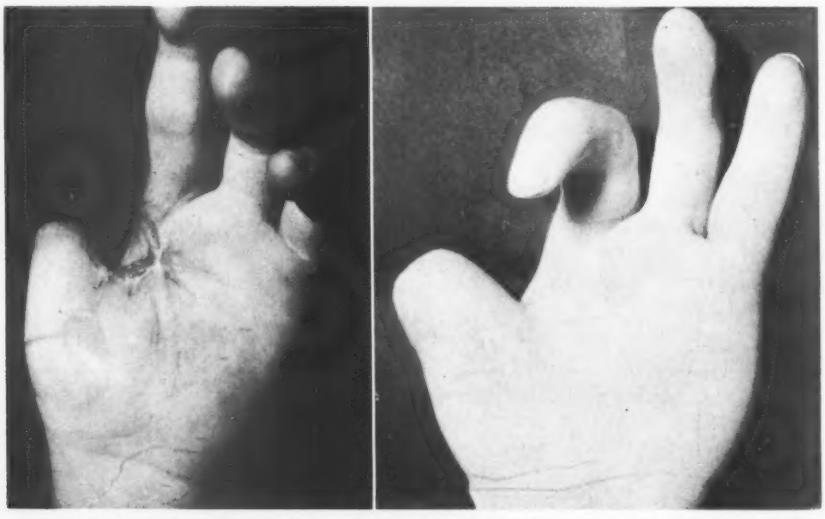

FIG. 3. The patient was a sixteen year old boy. *Left*, hand eighteen months after primary injury, at which time the boy sustained loss of the middle finger. Removal of the third metacarpal at the time of primary repair and limiting inroads into less severely destroyed tissues resulted in this functioning limb. Note particularly the preservation of the thumb remnant. *Right*, indication of the range of movement available to the patient.

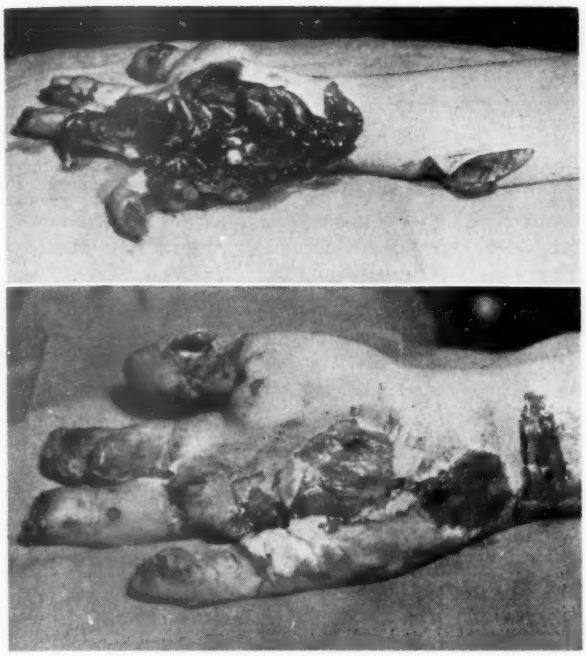

FIG. 4. Injury to the right hand and forearm of thirteen year old boy following explosion of a homemade rocket. *Top*, note the extent of soft tissue destruction which included amputation of distal phalanges of three fingers, open fractures of carpal bones and metacarpal bones and distal end of the radius and ulna, loss of an extensive portion of the median nerve and severance of the ulnar nerve. *Bottom*, seven days after primary repair, showing satisfactory healing taking place with healthy granulation tissue which would accept split-thickness grafts.

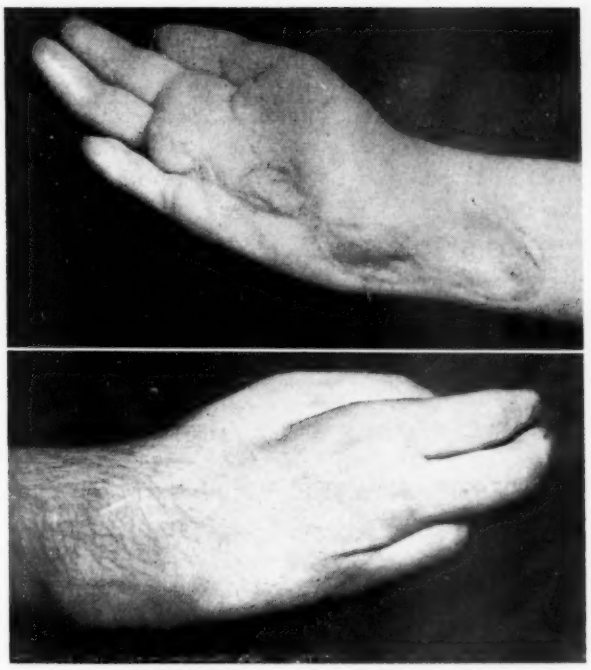

FIG. 5. Shows the same hand as Figure 4 six months after primary repair, revealing well healed soft tissue with skin covering all traumatized areas. Active motion at this time is limited to active opposition of the thumb. Passive range of motion to 40 degrees is present in the metacarpophalangeal and interphalangeal joints.

injured tissues, the ever present danger of infection and the certainty of post-traumatic edema make this a dangerous course to follow. Tension must be avoided in closure and skin grafts employed, even from the outset.

Inevitably, more or less scarring and contracture develop in the course of healing. In order to combat the detrimental effects that this result will have on future procedures, the hand must be dressed in the position of function. Scarring and its consort, contracture, draw much of their potentiality from edematous fluid. Maintenance of the hand above elbow and elbow above shoulder position is one step in the management and prevention of these complications. Infection by aerobic and anaerobic organisms requires constant atten-

FIG. 6. Shows the same hand as Figures 4 and 5. *Left*, three years after primary repair and multiple secondary procedures including skin grafting, tendon graft and nerve grafts. *Center and right*, indicating the range of motion present, particularly important being the ability to oppose the thumb through all remaining digits. Sensation is intact over the lateral three digits.

tion throughout the management of the case, both pre- and postoperatively. Shock and associated injuries must always be treated.

In the postoperative period, prior to grafting and reconstructive procedures it is important to maintain remaining function and encourage the use of the more definitively repaired structures. Tendons require about three weeks to attain functional strength. At this time active exercises may be instituted—active, not passive. The trauma involved in attempts to manipulate joints and soft tissues passively results in the further development of scar tissue and contracture deformity. Secondary procedures involve the application of skin, tendon and nerve grafts, and even the construction of digits.

The following case will serve to underline some of the factors previously considered in the management of these injuries. (Fig. 4, *top*.)

A thirteen year old boy sustained severe injury to his right hand and forearm consisting of traumatic amputation of the distal phalanges of the index, middle and little fingers, and the whole of the ring finger to the base of the proximal phalanx. In addition he had open fractures of the carpal bones together with the fourth and fifth metacarpals and the distal end of the radius and ulna. The little finger and hypothenar eminence were separated from the rest of the hand by a longitudinal split extending to the distal margin of the interosseous membrane of the forearm. There was marked loss of skin of the palm of the hand and flexor aspect of the wrist. All the flexor tendons in the hand except the flexor digitorum profundus to the little finger were severed together with the median and ulnar nerves. The median nerve was avulsed for 12 cm. Two lacerations in the flexor aspect of the forearm involved the flexor carpi ulnaris and flexor digitorum sublimis. Primary treatment involved conservative débridement, amputation of the stumps of the distal phalanges of the index, middle and little fingers, and removal of the remnants of the ring finger, including a comminuted fourth metacarpal. The little finger and hypothenar eminence were united to the rest of the hand by a transversely directed Kirschner wire through the fifth and third metacarpals, the fourth metacarpal having already been removed. The wound was then closed without tension. The whole procedure was performed using a pneumatic cuff to provide hemostasis. The cuff was released several times in order to avoid compromising an already precarious blood supply. Aureomycin® gauze and a padded dressing with an anterior plaster splint were used to immobilize the limb. Antibiotics and tetanus antitoxin were used in the postoperative period. Seven days later the dressing was changed under general anesthesia and the granulation tissues appeared to be clean. (Fig. 4, *bottom*.) At this time secondary closure of the forearm wounds and split skin grafting of the deficient areas of the hand were performed. The patient was discharged six days later. After six months the skin grafts were well healed and the appearance of the hand was fairly good. (Fig. 5.) Nine months after primary treatment the patient underwent another operative procedure. This involved removal of the navicular and hamate bones, with arthroplasty of the wrist. These two carpal bones became injured and displaced in the primary injury. The median nerve, which had been avulsed for approximately 6 inches, was united with a cable graft employing the ulnar nerve. Tendon grafts to the index and middle fingers were also inserted, using the sublimis tendons of these fingers. One year later tendolysis of the flexor tendons of the index, middle and little fingers was performed. When seen three years later the patient had a fairly satisfactorily functioning hand. He was able to use it quite well and had a good, useful extremity. (Fig. 6.)

SUMMARY

Injuries to the hand from homemade rockets are becoming much more frequent. In the first six months of 1958 eight severe injuries were encountered in the Detroit area alone. Prevention of these injuries is extremely important.

The first procedure is extremely important. One should keep in mind the necessity for secondary procedures, and the ultimate aim is maximum function. The surgeon is aided to a considerable extent in the treatment of these particular injuries by the young age of the patient, with his excellent recuperative powers and remarkable capacity for compensating and adapting to disability.

The Level of Amputation in the Third Finger

ROBERT E. CARROLL, M.D., *New York, New York*

INJURY to the hand is a major disability to all. It is impossible to prepare for the diminution of function and the frequently extended course of repair or reconstruction. Trauma precipitates all this unexpectedly for both the patient and the surgeon. Thus it is necessary to review experience and procedure frequently, to equip fully those who would care for the acutely injured person. All will agree that the excellence of the final result will depend mainly on the experience of the physician rendering the initial care. Frequently his care will produce such a fine result that little further can be added. This paper is intended to serve as a guide or suggestion to all those who care for the injured hand.

Amputation of any portion of the hand produces great emotional stress along with loss of function. While it is quite normal to find this distress over the loss of all or part of an extremity directly after trauma, it is certainly not normal to find it prolonged with resultant personality changes. In dealing with the trauma of amputation, it is best to do what is necessary to ensure on completion a hand which will be useful and without pain on healing. Should this not be possible at the initial treatment of the injury, any patient will appreciate an explanation of a course of action that will soon return his hand to function. It is believed that better hands will be obtained if certain facets of hand surgery are illuminated by attention to one specific problem rather than to broad general principles.

The third digit of the hand, frequently referred to as the middle or long finger, is the main axis in anatomical construction. Both abduction and adduction are determined from this point of reference. The function closely parallels that of the index finger. There is relatively little motion to be found at the base of the index and middle fingers in the carpometacarpal joint. This gives stability and power to grasp. Both the index and the middle fingers are the firm opposing post to the pinch of the thumb. Removal of any portion of the row of phalanges or metacarpals must be considered with great care.

There is practically no guide to which a sur-

FIG. 1. Any amputation through the proximal phalanx of the middle finger leaves a functional deformity in the hand when shorter than the full phalanx. The projecting stump is frequently traumatized. A gaping defect is created in the cupped hand. The short segment prevents approximation of the second and fourth rays.

FIG. 2. Resection of the remaining phalanx and metacarpal head down to the narrow shaft has been suggested as one method for improving the function.

FIG. 3. The best solution to the problem is total resection of the fragments of the third ray. Thereafter the second (index) ray is transposed to the position formerly occupied by the third (middle) ray.

geon can turn for discussion of levels for amputation in the third digit. Most reference texts [1,3,4] deal only in generalities and do not fully consider the problem which faces the surgeon as he prepares to give his patient the best possible finger. On many of the principles all are in agreement. It is believed that we should save as much as possible of any injured digit. It would be better stated that we should save as much of that digit as will afford the best painless function on healing. Having this in mind, we should like to consider the levels of amputation in the third finger.

DISTAL PHALANX

The method of care of the distal phalanx of the third finger is the same as that of the index, fourth and fifth fingers. The distal tuft can be resected to give a well rounded tactile pad with the protective nail intact. This method holds true for amputation in the middle third of the phalanx. Amputations leaving the base of the distal phalanx are of little value. The end of such a digit is bulbous. There is no remaining lever for the distal interphalangeal joint to be of value. Nail matrix remains and produces painful horns that often lead to chronic infection or tear by catching on fabric. When only the base of the distal phalanx remains, it is better to use a level of the distal portion of the middle phalanx. The extensor tendon and the flexor profundus tendon are divided and allowed to retract. No attempt should be made to secure them. The condyles of the distal portion of the middle phalanx are rounded off to give a dome-shaped end to the stump of bone.

MIDDLE PHALANX

Amputation by disarticulation of the distal interphalangeal joint produces a bulbous tip. Bursae do develop here, giving a poorly functioning, unsightly tip. The projection of the articular condyles of the distal portion of the middle phalanx frequently causes pain with grasp. It is much better surgery to fashion the tip of the phalanx into a cone by removing the

FIG. 4. Total resection of the residual ray is also better. This is frequently the method of choice in dealing with tumors. Removal of the metacarpal block permits approximation of the second and fourth rays.

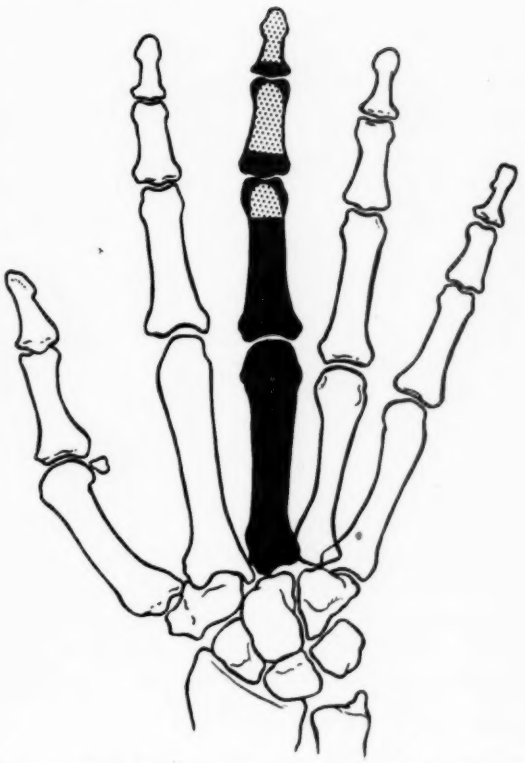

FIG. 5. This diagram shows, by the stippling, the acceptable levels of amputation in the middle finger. Amputation through an area here indicated by solid black is not acceptable for the best function of the hand.

condyles. Any level of amputation down to the base of the middle phalanx is acceptable.

Again it is a problem when only the base of the middle phalanx remains. In general, the same principle is accepted as indicated in the distal phalanx. However, a little more latitude may be permitted at this joint. Retraction of the flexor profundus tendon may not have occurred beyond this point. Hemorrhage leading to scar tissue in the flexor sheath has on some occasions limited the retraction of this tendon. The power of flexion here would then be received from both tendons. If the joint is at all useful and not painful, one might consider terminating the amputation here; otherwise the site of election would be through the tip of the proximal phalanx.

PROXIMAL PHALANX

No amputation should take place through the proximal interphalangeal joint. The same problem occurs here as outlined in amputation of the distal interphalangeal joint. It is much better to cone off the tip of the proximal phalanx. Length must be preserved in this phalanx. A level of less than three-quarters of the proximal phalanx is not acceptable.

The short stump frequently lacks the pull of the flexor profundus and sublimis tendons. It contributes little to grasp and leaves a defect in the cupping of the phalanges. The tip of the stump projects from the fist and is traumatized by repeated blows. Moreover, the presence of this portion of phalanx serves as a block to keep the index and fourth fingers apart. (Fig. 1.) It is my opinion that if only this short portion of the proximal phalanx is to remain, it would be better to remove it along with the entire third metacarpal. At a later date a better hand can be fashioned by transposition of the index ray to replace the missing third digit.

THIRD METACARPAL

At some point in the development of traumatic surgery it has been said that preservation of the metacarpal head, and thus a broad palm, is necessary for the hand of a working man. This is an arbitrary axiom compounded by a surgical philosopher and not someone familiar

with the problem of the injured hand. It is especially magnified in an amputation at the third metacarpophalangeal joint. Here the head of the metacarpal serves to maintain a gap in the grasping hand. The defect prevents the handling of small objects at work and especially the handling of coins. Furlong [2] believes that it is better to resect the metacarpal head down to the narrower shaft. (Fig. 2.) I believe that a much better hand is produced by one of two alternative methods. The most useful hand is produced by removing the third metacarpal and transposing the index ray to replace the third finger. (Fig. 3.) The other alternative is to resect the third metacarpal completely, including the base. The adjacent rays will then shift slightly to take up the gap in the hand. Even the removal of the base of the metacarpal aids by allowing greater excursion in shifting. Often this second method is used when the third ray must be excised in the treatment of tumor problems. (Fig. 4.)

SUMMARY

The levels at which the third digit should be amputated are discussed (Fig. 5.) This digit was selected and discussed because of the role that it plays as the main axis of hand function. Preservation of length will depend on obtaining the best permanent finger for function. Disarticulation through a joint is unacceptable as a final procedure. Should less than almost the entire length of the proximal phalanx of the third digit be saved, it is better to remove the phalanx and the metacarpal. At that time, or as a second procedure, the index ray should be transposed to replace the third digit. Not only does this step produce excellence in function, but also it produces a most acceptable cosmetic result. This discussion of amputations will prove to be of help in both acute trauma and elective amputation. It is presented with the hope that the initial surgery may be the only procedure necessary to produce a satisfactory extremity.

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DISCUSSION OF PAPERS BY DRS. DRUCKER, HUBAY, HOLDEN AND BUKOVNIC; SCHLESINGER AND LISS; ARCARI, LARSEN AND POSCH; AND CARROLL

Michael Livingood Mason (Chicago, Ill.): I would like to say a word or two about the paper by Drs. Arcari, Larsen, and Posch. The principles which the authors have enunciated in the care of these injuries of course are the same as those for the care of any of the open wounds, that is, early treatment, cleansing of the wound and excision of all tissue that is going to become necrotic.

I like the fact that the authors have emphasized one should not sacrifice anything that is going to be viable, because you do not know at the end of the procedure, possibly while you are attempting to reconstruct the hand, how much use you can make of the tissue that has been saved. Only a little skin or a few bones may be saved, but you can often reconstruct digits or a grasping mechanism from structures that look as if they were not of any value at all.

The next principle is that of closure, and I believe that practically all these wounds of the hand, no matter how poor they may look, if treated within a reasonable period of time can be closed certainly without tension. Save all skin tags that are possible to save and use them for closure. When you cannot close any more of the skin without tension, employ split skin grafts for immediate primary closure; following this mold the hand into the position of function and put on a compression dressing, and this will give you a start on your reconstruction. If the hand can be healed within a reasonable period of time in the position of function, reconstruction stands every chance of being successful.

I would like to discuss one case which was not quite as bad as the one the authors presented. The patient was a young boy who made a bomb with saltpeter, sulfur and other materials, and carried it between his legs in an automobile to the country to explode it. However, it exploded before he got to the country, and blew up both the right and left hands. The knees and face were injured, and multiple injuries were sustained.

At surgery the right hand was completely covered with skin. The final appearance of the hand was not very good, but the hand was completely covered with skin.

The left hand was not quite as badly injured, but it also was immediately closed, partly with suture and partly with skin grafts, molded into the position of function and then covered with skin grafts.

Subsequently a number of reconstructive procedures were performed consisting essentially of correction of adduction contractures of both thumbs, applying skin pads to the tips of the right thumb and the middle finger, and a tendon graft to the left thumb.

CHARLES G. JOHNSTON (Detroit, Mich.): Dr. Mason has given such a fine summary of the paper by Drs. Arcari, Larsen and Posch that there is nothing more for me to add.

I would like to point out that this injury is not uncommon, at least in the city of Detroit. These injuries happen to teen-age children, and for the most part all those whom I have seen in the Receiving Hospital of the City of Detroit have been bright children. They have not been backward in any sense at all. Hence the loss in these children is not only in relation to the amount of suffering and trauma they endure, but also that the resulting hand usually leaves them with a psychologic defect which is somewhat difficult to handle because they are pretty well limited in what they can do.

I do not think I have seen this type of injury in an adult in the city of Detroit.

We did see very much the same problem in the military when servicemen took the percussion caps out of shells for souvenirs, and here again this happened not only to novices. I remember one case in which the sergeant who was in charge of ammunition was instructing another man on how to remove it. As a plane went by he looked up, and of course at that moment he lost a good part of his hand.

I believe the philosophy which has been so frequently stated in relation to treatment is well worth while, that is, save all the structures you can—even though it looks for the moment in the acute stage that you may not have to use it—because, as has been pointed out, you may need a piece of bone, tendon or other structures for repair at a later time.

One other point, I think we all have a tendency to squeeze just a little bit, to get as much coverage as we can, and sometimes we find ourselves covering tissue which is not too satisfactory with badly damaged skin, and this under tension.

The concept that these wounds must not be closed under tension I think is very important. This illustrates what has been said about the importance of first aid and the emergency service. Such wounds are not something for the inexperienced surgeon to treat because they can tax the ingenuity and the skill of even the best and should require the attention of the best services and surgeon available.

JOHN J. CRANLEY (Cincinnati, Ohio): I would like to discuss Dr. Schlesinger's paper on the carpal tunnel syndrome. I think we would have no basic disagreement with him, but being interested in peripheral vascular disease, our approach is somewhat different.

We start with the concept of Raynaud's phenomenon, which is a simple complex whereby the patient has coldness, numbness and tingling of the fingers or toes. In the more severe forms it goes on to atrophy of the skin, subcutaneous tissue and muscle, and may even progress to the point of gangrene.

We see this phenomenon much more frequently in the cold climate of New England than in the warm climate of Cincinnati. Whatever the cause, however, the end organ is distal arteriole. It is vasospastic arteriolar disease. As Dr. Schlesinger pointed out, there are many, many patients with acroparesthesia or Raynaud's phenomenon of the finger and we simply do not know all the causes. One cause that seems to be becoming clearer to us is traumatic neuritis.

We have not been able to distinguish between Raynaud's phenomenon produced by injury to the median nerve in the carpal tunnel or injury to the median nerve anywhere else along its course, as for example in the axilla due to the use of a crutch.

We have seen only three patients in whom it seems certain on clinical grounds that the injury was in the carpal tunnel. Two of these were patients who pounded their hands heavily on a metal object while at work, and the third was an elderly woman who was always leaning on a right angle type of cane following fracture of the hip.

In all three of these cases there was complete recovery following elimination of the trauma.

ROBERT E. CARROLL (closing): Dr. Schlesinger graciously asked me to discuss his paper several months ago. Since this subject is of special interest to me, I am delighted to comment on his presentation.

This is an excellent paper to guide all who would enthusiastically ascribe all painful hands to compression of the median nerve in the carpal canal. However, I am a little bit appalled at the great list of neurological diagnoses which I saw in the first illustration. Should the differentiation between a carpal tunnel problem and any of the other diagnoses be at all difficult, a consultation might be beneficial both to the physician and patient.

The diagnosis of acroparesthesia should not be lightly made. It too frequently is appended to any case of painful hands. Careful review and further examination will reveal specific diagnostic signs leading to a specific entity which can be helped. While pain at night may be present in acroparesthesia, it is also present with median nerve neuritis. Watch for the additional signs of muscle atrophy, numbness of the first three digits, pain with tapping of the median nerve, and increased pain and numbness in only the first three digits on acute wrist flexion.

There is one other section of Dr. Schlesinger's

paper which I would like to consider. This deals with the operative site and the technic. While the authors have used a transverse incision for exposure to divide the volar carpal ligament, I am strongly opposed to this incision. To me it is peephole surgery which brings with it potential complications. In one case the surgeon performed three operations before the carpal ligament was completely divided. Division of the recurrent median nerve at the distal edge of the carpal ligament is easily accomplished. Section of the superficial volar arch with resultant hematoma and necrosis of the palm can occur. A curvilinear incision in the interthenar crease has the advantage of total direct exposure of all structures in the carpal canal. It can be continued into the forearm by crossing the flexion crease obliquely. Moreover, it heals just as rapidly as the transverse incision and has less residual, apparent scar. The authors are absolutely correct in decrying a vertical incision from palm to forearm.

When performing surgery of the hand it seems to me to be a fundamental or basic principle to use a tourniquet on the arm. This places the surgeon in the position of having absolute control over the vascular system. It allows ease of definition in locating structures and thus increased skill in completing the procedure. This would seem especially true in dealing with the median nerve in the carpal canal. There are no disadvantages or complications with the use of a tourniquet.

Charles A. Hubay (closing): We have presented a mass of neurologic data with regard to post-traumatic sympathetic dystrophy. We have been concerned with the over-all category into which many of these disease entities are thrown. The problem that has troubled us most in the last few years has been the fundamental neurophysiologic pathway of pain.

The more recent data and neurophysiologic information that have been available to us in Cleveland from Drs. Collins and Randt regarding the unmyelinated C fibers is valuable in understanding some of the pain pathways in sympathetic dystrophy and causalgic states. The syncytial type of arrangement of the C fibers aids us in understanding an ephapse between the sympathetic efferent fibers and the somatic afferents.

One thing that is still puzzling to us, which we cannot really explain on the basis of our present knowledge and our theoretic diagram, is the reason why some of these causalgic states come on so long after injury. However, in reviewing some of our own cases we believe that these patients fundamentally are emotionally labile individuals who very often have medicolegal aspects of trauma entering into this syndrome. From a diagnostic point of view, we try to differentiate between true causalgia, mixed peripheral nerve lesions and sympathetic dystrophies in which we cannot actually anatomically localize such a nerve injury.

Joseph L. Posch (closing): I would like to discuss the carpal tunnel syndrome that Dr. Carroll mentioned. I sincerely believe that the S-shaped type of incision, or the longitudinal semi-curved incision, is the best one to employ. It does allow better exposure than the transverse incision does, and adequate section of the volar carpal ligament is possible. This, however, must be done, I believe, in a bloodless field with adequate anesthesia. We have had one patient referred to us in whom there was section of the recurrent branch of the median nerve following a section of the ligament.

In regard to the level of amputation of the third or middle finger, we have had no experience in transpositioning these digits. The only contact that we have had with this type of surgical procedure is treatment of the non-union which occasionally results when the surgery is performed elsewhere.

I am sure that Dr. Carroll will explain in detail the exact techniques involved in his paper so that these non-unions can be avoided in the future.

I would also like to comment briefly on our paper on injuries to the hand from home-made rockets. This rather disastrous problem is encountered with increasing frequency. At first these injuries were caused by home-made bombs. However with the advent of the Explorers, Sputniks and so on, we now are seeing a large number of injuries from home-made rockets. Not infrequently, these injuries will follow a new story in the magazine section of a Sunday newspaper. Here, meager details are provided on how to make these rockets; inexperienced youths attempt to do so without proper training or supervision and suffer the severe explosive wounds that have been demonstrated here. For example, the first case that was presented in which the ring finger had been completely avulsed occurred approximately five days after one of these articles appeared in a local newspaper. This article very carefully described how one boy in California made 150 rockets and then exploded them. I will not dwell on how they were manufactured, or you might be tempted to do likewise.

There have also been some articles in the lay press. Fortunately, recently some of these have emphasized the prevention of these injuries and emphasized the fact that these rockets should be made under adequate supervision.

At this time we, too, would like to stress prevention of these severe injuries from home-made bombs and rockets. If this cannot be done by adequate education, laws will have to be passed in an endeavor to prevent these severe injuries that used to occur only on the Fourth of July but now occur during the entire year.

William R. Drucker (closing): I have two cases of rocket injuries to add to the series presented. They both occurred in students at the Case Institute of Technology. Both patients are a little

older than the average patient in the group reported and their injuries were of the order of magnitude that has been discussed.

With regard to sympathetic dystrophy, there is one point I wish to emphasize—a point becoming more frequently noted, particularly in the German literature: Therapy should not be delayed too long. The disease is insidious. The hands frequently look like they are doing well, yet structural changes are continuing. If conservative measures, which should be tried first, do not bring about complete relief, then some form of sympathetic interruption should be instituted very early. We start with blocks; and if this method is not successful, we go ahead with surgical removal of the sympathetic ganglia.

EDWARD B. SCHLESINGER (closing): I would like to thank the discussers for their stimulating comments. Dr. Carroll speaks as an expert hand surgeon, and he should always be listened to carefully. Our point of view, however, is as follows: First, in regard to his remarks about the neurological entities, we call them as we see them, and these are some of the conditions which have come through our offices and the wards of the Neurological Institute diagnosed as the carpal tunnel syndrome. No one can quarrel with the facts, and these are the facts. Dr. Carroll, at his terminus, sees the problem with a hand surgeon's orientation and for him, as he so aptly put it, the problem is right in the hand. Certainly one has no desire to quarrel with experts who have given the problem careful thought. Such is not the purpose of our presentation and whatever incision he chooses to make, or anyone who has dealt intensively with the subject, cannot be quarreled with.

As far as Dr. Carroll's criticism of the transverse incision is concerned, I must indulge in a very trite platitude: "The proof of the pudding is in the eating." We have had no subsequent failures using the transverse wrist incision. Using a simple approach one turns what can be a laborious surgical performance into a five- to fifteen-minute operation with an excellent functional and cosmetic result.

We are aware of the hazards mentioned, are alert to them and have met none of them. So far as the Esmarch bandage is concerned, I would agree entirely with Dr. Carroll that if I performed and were trained to perform extensive hand surgery, I would most certainly want to use a tourniquet. For the simple horizontal wrist incision this is ordinarily not necessary.

We believe that the transverse incision has proved to be useful, efficient and free of the complications of other incisions. On those grounds we offer it for consideration. It certainly is not the incision for a case in which there is need for very careful exploration of all the local structures and tendinous attachments. Our chief concern is to derogate snap diagnoses, unnecessary procedures and poorly placed incisions.

The Treatment of Metastatic Fractures with Internal Fixation

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IN recent years the internal fixation of pathologic fractures has become a more commonly accepted procedure. The principles of internal fixation of these fractures and the indications for such treatment have been described by McLaughlin [*1*], with particular reference to pathologic fractures of the femoral shaft.

In this day of earlier and more adequate treatment of cancer many patients present themselves with a fracture as the first evidence of their disease. Often these patients are in excellent general condition and pursuing a completely normal and productive life. A solitary skeletal metastasis may result in fracture many years following the original surgical therapy. The occurrence of a spontaneous fracture of the femoral neck in a relatively young person pursuing a productive and active life, who is otherwise in excellent health, is a terrifying and catastrophic event both for the patient and the family. Some types of cancer may be palliated for significantly long intervals following metastasis, and the presence of a solitary metastasis involving a vital area of a weight-bearing bone is the ideal situation in which an active attempt should be made, not only to control further progression of the systemic disease but also to prevent inevitable fracture through the lesion of bone and the subsequent disastrous results to the patient. It is for these reasons that the theory of prophylactic internal fixation, or more accurately stabilization, of these imminent fractures has evolved. Metastatic cancer in bone often produces pain. Pain should be a signal that adequate clinical investigation of the involved region should be undertaken, particularly if the pain is in an extremity after a known primary lesion has been treated. It is probable that pain from a metastatic lesion in a weight-bearing bone may be due in part to the stress placed on this weakened area by weight-bearing. Accordingly, stabilization of such an area before fracture occurs will frequently relieve this component of the pain and prevent inevitable fracture in many cases. Mechanical stabilization of the area in no way precludes the recognized forms of active radiotherapeutic, hormonal and ablative attack upon the primary disease process.

As stated by McLaughlin [*1*], the majority of pathologic fractures of the extremity involve the femur and humerus, and these fractures are the most amenable to internal fixation. Prior to the use of such treatment the relatively well patient with an isolated pathologic subtrochanteric fracture of the femur was immediately confined to a life of pain, complete bed rest in traction or plaster and complete incapacity—this aside from the emotional drain upon his or her family. The resultant nursing care and expense incurred is a great problem to those concerned. For these reasons internal fixation of appropriate metastatic fractures is a significant advance in the management and care of such a patient. To be sure there are instances when it is not indicated, particularly if there is far advanced disease and operative interference is an unwarranted risk.

The excisional treatment of metastatic osseous lesions is an accepted and important method of therapy. This surgical attack has its prime indication for metastatic lesions of the clavicle where either partial or complete excision can be performed to prevent fungation which is particularly common in this region.

SITES OF FRACTURE

Cancer of any origin may metastasize to the osseous system. The most common primary lesion producing metastases to the bone in the female is carcinoma of the breast. This tumor is being treated earlier definitively, and as a result isolated osseous metastases are seen more frequently not unusually several years later. The most disabling fracture is that involving the lower extremity. Subtrochanteric fractures of the femur seem by far the most common. Fractures of the neck and lower femoral shaft follow in that order. As has been noted by McLaughlin, pathologic fractures distal to the knee and elbow are unusual.

Metastatic fractures of the upper extremity most amenable to internal fixation are those involving the humerus. The shaft is most commonly involved. Metastatic fractures occurring in the pelvis, spine and distal areas of the extremities are without the scope of treatment by internal fixation.

INTERNAL FIXATION

Indications. The most important indication for internal fixation of a metastatic fracture is pain. These fractures are extremely painful and a previously comfortable and active individual is suddenly disabled, particularly if the fracture involves a weight-bearing bone. If a patient can be relieved of his pain and mobilized on crutches or even a wheelchair, much has been gained from a medical, social and emotional viewpoint. Not infrequently the death of such patients is slow, requiring several periods of hospitalization, and any relief from this financial burden is welcome both to the patient and the family.

One must not overlook the emotional factors involved in terminal illness. A patient's morale can be greatly strengthened by the relief of pain and the ability to get around. The return of this patient to his home in comfort, albeit on crutches or in a wheelchair and perhaps for only a short interval, is of immeasurable benefit to all concerned.

Contraindications. As with any surgical procedure, there must be adherence to certain principles of its employment or its basic value will be lost. Each fracture and patient must be considered individually, and in each instance the clinical problem is different. In general it can be stated that internal fixation is not indicated in the seriously ill terminal patient with widespread osseous and visceral disease. Internal fixation is rarely justified in extensive osseous disease from multiple myeloma with numerous fractures. Other contraindications due to multiple involvement can make the procedure unjustified. It should be borne in mind that when a lower extremity is affected, investigation of the opposite limb is indicated. In general it may be stated, however, that the majority of patients withstand the surgery without difficulty after proper preoperative preparation and good postoperative care.

Wound Complications. Internal fixation of a metastatic fracture necessarily entails surgical exposure of an area of tumor. Complications due to exposure of such an area have not been significant. Gentle handling of tissues and the avoidance of hematoma are important factors in the prevention of wound complications. As cancerous tissue is highly vascular, a considerable amount of bleeding is to be expected if the fracture site is exposed or manipulated. Firm pressure and patience may control this problem. The incidence of postoperative wound infection has been no higher than with other types of tumor and fracture surgery. Fungation of the tumor through the wound following internal fixation has not been a problem. The principles set forth by Coley [2] for the open biopsy of tumors of bone must be strictly adhered to, namely, accurate and tight closure of the surgical wound. Drains or packing of any type should be avoided in these cases. I have observed one instance of obvious seeding of the operative wound by cellular implantation during surgery. In this instance several small subcutaneous tumors occurred in the operative scar four months after internal fixation of a pathologic subtrochanteric fracture of the femur secondary to bronchogenic carcinoma. These implants were excised with local anesthesia and at no time were they a problem to the patient.

Dissemination of Disease. As stated by McLaughlin, there seems to be no significant danger of producing disseminated cancer following internal fixation of a metastatic fracture. Neither is there convincing evidence that the insertion of an intramedullary device carries tumor cells to the distal segments of a bone to produce new lesions in that area. When new lesions appear at the proximal or distal extremity of the femur after intramedullary nailing of a fracture of the shaft, their presence most

FIG. 1. Metastatic lesion of the left proximal femur seen in June, 1957.

FIG. 2. Lateral view of femur shown in Figure 1.

likely antedated surgery of the fracture and bears no relation to its surgical fixation.

Radiotherapy. Postoperative radiation to the fracture site is indicated in radiosensitive lesions. This treatment can be started soon after surgery, and when accurately and adequately administered may control progression of the local disease for extended periods. Indeed, not infrequently following stabilization and adequate radiotherapy the fracture may heal.

PATHOLOGIC FRACTURE WITH PRIMARY OSSEOUS NEOPLASMS

The most commonly encountered primary malignancies of bone such as osteogenic sarcoma and chondrosarcoma, when associated with pathologic fracture through the tumor, do not lend themselves to treatment with internal fixation, as the primary disease must be treated most frequently by amputation in the absence of demonstrable metastasis. Internal fixation of fractures through Ewing's sarcoma and reticulum cell sarcoma of bone is not indicated, as these tumors are extremely radiosensitive and it is unusual for healing not to occur after radiotherapy associated with the indicated external support.

PROPHYLACTIC INTERNAL FIXATION

It is not uncommon with metastatic cancer to encounter lesions of bone in areas where fracture is impending. These lesions are often solitary areas of destruction involving the proximal end of the femur. During the early stages of disseminated cancer, notably from the breast, the patient may be for all intents and purposes in good health, gainfully employed and leading a normal life. Pathologic fracture in a bone of the lower extremity in such a patient is a catastrophe. Stabilization of the weakened area of impending fracture involving a weight-bearing bone by suitable internal fixation, combined with appropriate postoperative radiotherapy and chemotherapy, may well prevent fracture with all its dire consequences and provide the patient many more months of comfort. Similar lesions involving bones of the upper extremity are not as likely to cause fracture as those of the lower extremity.

The indications for prophylactic internal fixation necessarily vary in each individual patient. In general it is indicated in the lower extremity when there is a relatively localized area of bone destruction in a region where fracture is impending. It should be emphasized that the skeleton should be surveyed for other lesions, with particular emphasis placed upon the opposite extremity. Methods of internal fixation are those techniques usually employed for fractures. For stabilization of areas involving the proximal femur a Smith-Petersen nail and McLaughlin plate or other similar appliance has been most frequently employed. The intramedullary nail is indicated for lesions of the shaft, and a plate can also be applied if necessary. For lesions involving the lower

FIG. 3. Condition sixteen months postoperatively (September, 1958).

FIG. 4. Lateral view of femur shown in Figure 3.

femoral shaft and supracondylar region of the femur, Rush nails may be inserted from below and provide suitable stabilization. Lesions of the humeral shaft may be treated prophylactically by intramedullary fixation utilizing either the Küntscher or Rush nails.

Metastatic lesions distal to the elbow and knee are not common. However, if these lesions are present, the usually accepted methods of appropriate internal fixation are applicable.

Pain resulting from an area of metastatic disease without fracture, for instance in the intertrochanteric region of the femur, may be strikingly relieved following stabilization of the area. It should be noted that properly and adequately administered radiotherapy to the involved area may not uncommonly result in healing of that particular lesion after prophylactic internal fixation. To illustrate the value of this form of treatment, the following case is presented in brief.

A thirty-nine year old single white woman underwent simple mastectomy for carcinoma of the left breast on March 15, 1957. On March 28, bilateral salpingo-oophorectomy was performed and a metastatic lesion was noted in the liver. Following surgery the patient returned to her secretarial job. She had no complaints until approximately May, at which time she began to notice mild aching pain in the region of the left hip. An x-ray film prior to surgery had revealed a 3.0 cm. destructive lesion in the lower left femoral neck near the calcar. (Figs. 1 and 2.) Radiotherapy to a tumor dose of 3,000/r was administered to the area. Skeletal survey and chest x-ray films showed no other metastatic disease. Accordingly, on June 13 a Smith-Petersen nail and McLaughlin plate were inserted to stabilize the impending fracture of the proximal femur. The patient made an uneventful recovery and was discharged from the hospital on the fifteenth postoperative day. She walked without pain and returned to her active secretarial job immediately, has been working actively and is doing so at this time without complaints referable to the hip. (Figs. 3 and 4.) Other recent metastatic lesions in the pelvis and spine have responded well to radiotherapy. The patient for all intents and purposes is leading a normal life.

This case illustrates strikingly the value of prophylactic internal fixation and the benefits that can be derived from it. It is believed that fracture almost certainly would have occurred through the lesion of the femoral neck and this would have been a disastrous event.

SUMMARY

The indications for, and the technique of, internal fixation of pathologic fractures due to metastatic cancer have been reviewed.

The benefit of such treatment to the patient and the socioeconomic factors relating to this treatment have been discussed in detail.

The value of prophylactic internal fixation for certain lesions involving particularly weight-bearing bones and the indications for such treatment have been presented.

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A Simple Aid to the Reduction of Abduction–External Rotation Fractures of the Ankle

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IT is axiomatic that manuevers employed in closed reduction of fractures should, in general, reverse the mechanism of injury. In accomplishing this, however, the presence of edema and the maintenance of reduction during splinting can present difficulties, even to the experienced. In the management of complex trauma to the ankle these factors are especially prominent.

Fractures involving varying degrees of abduction and external rotation of the foot and tarsus in relation to the tibia and fibula comprise more than three-quarters of all injuries to the ankle involving bone and ligament [1].

When sufficiently severe these forces not only can fracture the fibula but also can tear the ligamentous attachments between the tibia and fibula, rupture the deltoid ligament or avulse the medial malleolus wholly or in part. (Figs. 1, 2 and 3.) The talus, in other words, can slide laterally to produce the familiar deformity so well described by Pott [2] over 190 years ago.

Reversal of this pattern of injury can be achieved by taking advantage of the simple fact that the lower extremity, at rest, with the body supine, lies in external rotation. If the limb in this position is suspended from directly above by the great toe, then the ankle and foot, being of much less weight and mass than the leg and thigh, fall into adduction, internal rotation and supination.

In clinical application it is neither necessary nor advisable to suspend the limb by the great toe. If the limb is covered with stockinette, fastened to the upper thigh with elastic tape and suspended by the stockinette extending beyond the toes, the same effect occurs. Discomfort from hyperextension can be avoided by a sling beneath the knee. (Fig. 4.)

Not only is the lateral displacement of the distal elements of the injury automatically corrected, but also such edema as may have occurred subsides, as a rule, within twelve hours. This can be enhanced by the application of an elastic bandage over the stockinette a few hours after initiating suspension.

Patients are remarkably comfortable and as a rule only mild sedation and analgesia are required.

Portable x-ray films are taken after twelve to twenty-four hours of suspension. If position and alignment are satisfactory and there is no indication for operation, a full leg plaster can be applied over the stockinette without moving the patient from bed. A few weeks later the cast can be changed with somewhat less supination of the foot and ankle. Weight-bearing devices and short leg casts have not been used, and in fact are contraindicated in any but the simplest injuries to the ankle [3].

Fractures resulting from pure adduction or abduction forces in which a fracture of the medial malleolus lies at or above the level of the ankle joint are, of course, not suitable for the method, since the talus in suspension would almost certainly displace medially.

The problems of interposed tissue between fragments of the medial malleolus and torn ends of ligament or anterior capsule trapped in the joint remain. Portable x-ray films after a day or two of suspension will often settle the matter, showing slight separation of the tibial fracture faces, an unnaturally wide gap between the talus and the medial malleolus, or slight residual posterior displacement of the talus in the lateral view.

Appropriate operation can then be undertaken when edema has subsided.

Less easy to decide are those cases in which the degree of violence and the displacement seen at the first examination lead to the conclusion that rupture of the ligament is an

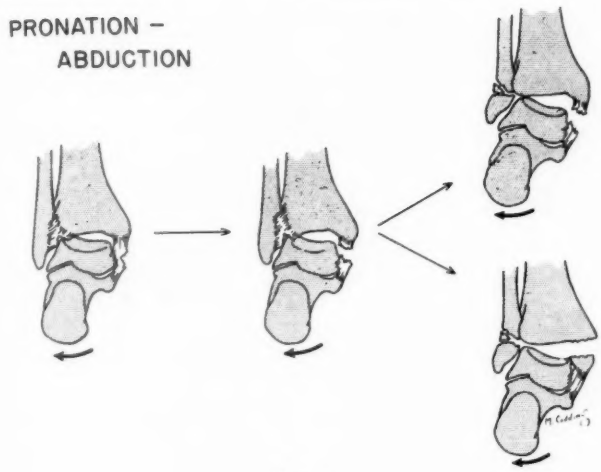

FIG. 1.

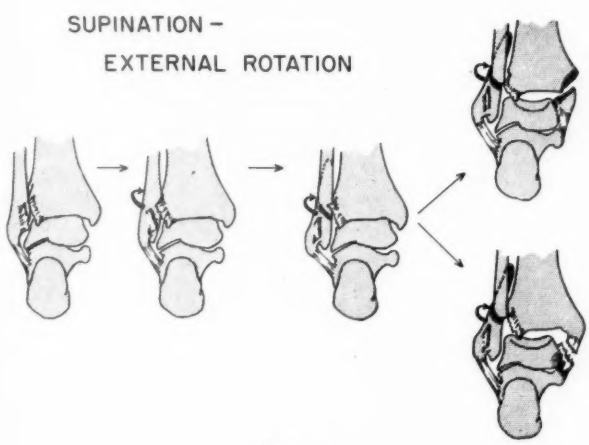

FIG. 2.

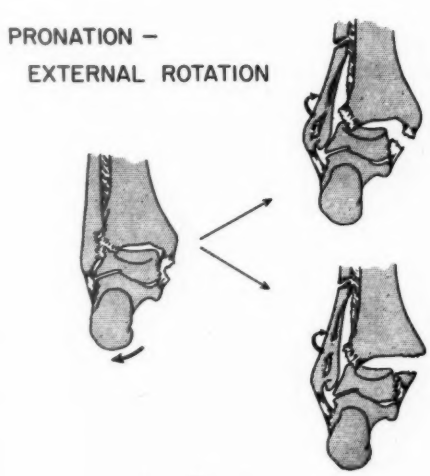

FIG. 3.

FIGS. 1, 2 and 3. Abduction–external rotation patterns of injury to the ankle (after Lauge-Hansen [1]). Combinations of forces can occur but are uncommon. The fibular fracture in pronation–external rotation injuries can be in the upper half of the bone. (FROM: QUIGLEY, T. B. Management of ankle injuries sustained in sports. *J. A. M. A.*, March 28, 1959.)

FIG. 4. Stockinette suspension for external rotation–abduction fractures and avulsions of ligament. The foot and ankle naturally fall into a position which is the opposite of the forces producing the injury. Reduction is often effected without further manipulation. (FROM: QUIGLEY, T. B. Management of ankle injuries sustained in sports. *J. A. M. A.*, March 28, 1959.)

essential part of the injury, yet portable films taken after a day of suspension show perfect position and alignment. The torn ends of ligament or capsule are not within the joint, but are they in perfect position, or twisted and rolled outside the joint in such a way as to heal with poor strength and function? In these, it seems justifiable to explore the ligament if contraindications such as age, poor circulation or poor skin are not present.

The recent experimental work of Clayton [4] has supported the clinical point of view that precise surgical restoration of torn ligaments is much to be preferred to immobilization and hoping for the best [5–7].

The method has been used increasingly often during the past four years at the Peter Bent Brigham Hospital, and no difficulties have been encountered. The following case histories will illustrate its usefulness in typical situations.

CASE 1. J. T., a twenty year old student, sustained a severe supination–external rotation injury to the right ankle while playing lacrosse. The foot was fixed to the ground by a cleated shoe and the force of a blow from another player's body against the thigh and hip produced the injury. When first seen an hour later there was marked edema of the ankle and gross lateral displacement

5 6

FIG. 5. Case 1. A supination–external rotation fracture of the fibula with rupture of the deltoid ligament one hour after injury.

FIG. 6. Same case. Reduction achieved by twelve hours' suspension in stockinette. The medial side of the joint was explored. The deltoid ligament was found avulsed from its distal attachment and rolled on itself but not trapped in the joint. Figures 5 and 6 from QUIGLEY, T. B. Management of ankle injuries sustained in sports. *J. A. M. A.*, March 28, 1959.

FIG. 7. Case 11. A severe supination–external rotation fracture in a forty-eight year old woman shortly after injury.

FIG. 8. Case II. Realignment produced by twelve hours' suspension in stockinette. Operation was contraindicated by the presence of an ulcer near the medial malleolus. The ankle was immobilized for eight weeks in a full leg plaster cast. Solid union and normal function were present six months after injury.

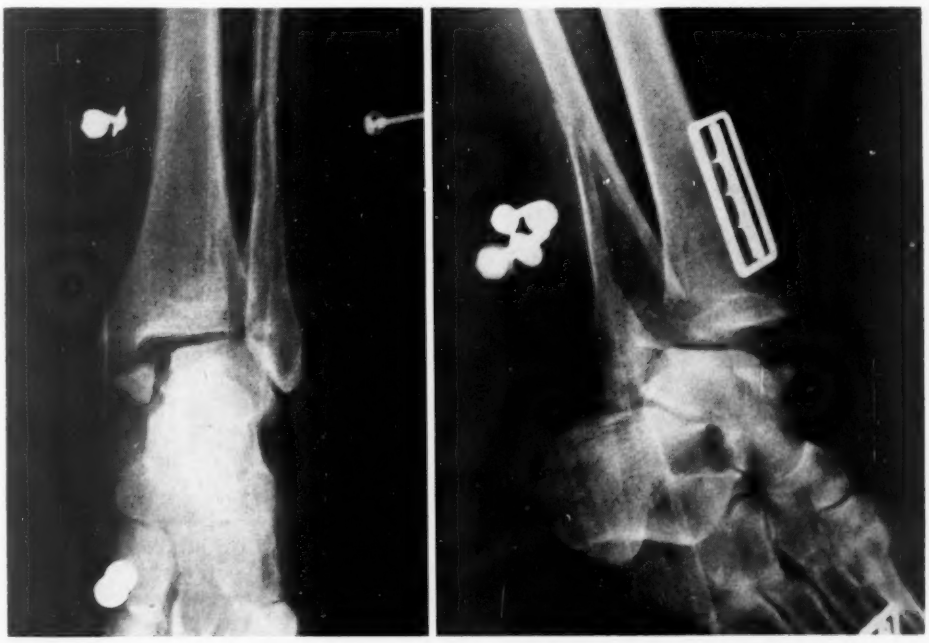

FIG. 9. Case III. Films taken shortly after a severe supination–external rotation injury in a fifty-four year old woman. Edema was marked.

of the talus, tarsus and foot. X-ray films (Fig. 5) disclosed a spiral fracture of the distal fibula and marked widening between the talus and medial malleolus.

Definitive treatment was delayed because contact could not be made with the patient's parents, who lived in another city. The limb was suspended in a stockinette; the foot and tarsus fell into adduction and internal rotation, and the patient was immediately comfortable. Portable x-ray films taken the next morning showed normal alignment of the bones of the ankle. (Fig. 6.)

It was thought that the deltoid ligament was almost certainly ruptured in view of the widening

FIG. 10. Case III. The effect of twelve hours' suspension in stockinette. Edema was reduced to the point that operation was possible.

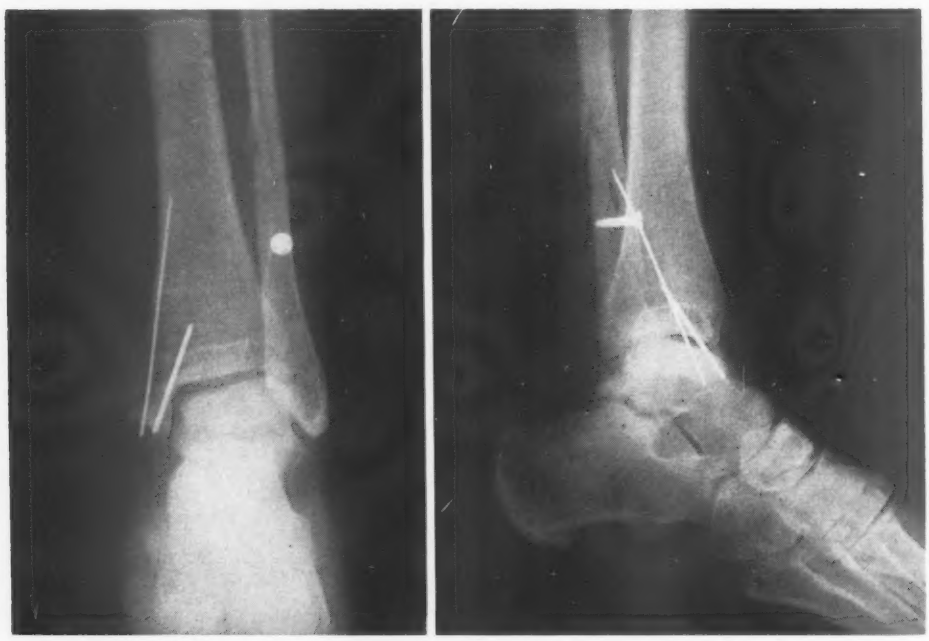

FIG. 11. Case III. Operative reconstruction carried out one day after injury. The medial malleolus was fragmented and could not be held with a screw. The peroneal tendons were found interposed between the fracture faces of the fibula.

of the mortise seen in the original x-ray films, but was not lying within the joint since the relationship of the talus and medial malleolus had been restored to normal. It therefore might well be retracted at its point of rupture, and surgical repair would be worthwhile.

Five days later, when edema had completely subsided, the medial side of the joint was exposed. The entire deltoid ligament and part of the adjacent anterior joint capsule was found avulsed from its distal attachment, retracted about 1.0 cm. and rolled upon itself. It was easily sutured into its normal position. The lateral side of the joint was not opened since anatomical reduction of the fibula and

tibiofibular relationships had been achieved, and bolt or screw fixation of the tibia to the fibula would have required another operation for removal of metal. The ankle was immobilized in a full leg plaster cast in moderate adduction, supination and internal rotation.

The cast was removed four weeks later and active exercise instituted. Weight bearing was allowed seven weeks after operation. Five months after injury the range of motion of the ankle was normal and the patient was playing touch football without difficulty.

CASE II. H. F., a forty-eight year-old woman, fell while entering a trolley car and twisted her left ankle. There was gross lateral displacement of the foot and ankle, moderate edema and an ulcer on the medial side of the leg extending down to the proximal flare of the medial malleolus. X-ray films showed a spiral fracture of the distal fibula characteristic of supination and external rotation forces, and a medially displaced almost horizontal flat spiral avulsion fracture of the distal three-quarters of the medial malleolus. (Fig. 7.) The anterior tibiofibular ligament was obviously ruptured and the deltoid ligament was intact. Open reduction and screw fixation of the medial malleolus, which would have been the treatment of choice, was contraindicated by the presence of the ulcer.

Fortunately, enough medial malleolus remained to prevent medial displacement of the talus by the adduction and internal rotation imposed by suspension in a stockinette.

After suspension overnight portable x-ray films (Fig. 8) showed reduction which, under the circumstances, was acceptable.

The ulcer was dressed and a full leg cast applied. Eight weeks later the cast was removed and at twelve weeks weight bearing was begun. Six months after the accident the ankle was functionally normal.

CASE III. M. C., a fifty-four year-old nurse, fell on ice and twisted her ankle. Examination and x-ray films (Fig. 9) showed gross lateral and posterior displacement of the tarsus and foot. As in Case II, the fractures of the distal fibula and medial malleolus were characteristic of supination and external rotation, but the twisting element of the injury had progressed to the point of partial posterior luxation of the talus on the tibia. Edema was marked.

After twelve hours of suspension the posterior luxation was reduced (Fig. 10), edema was minimal and the fracture of the fibula was fairly well aligned. The medial malleolus, however, was still grossly displaced and a fragment of bone was seen to be holding the talus and medial malleolus apart. At operation one day after injury the medial malleolus was found to be so fragmented that it could be held only by transfixing pins fashioned from Kirschner wires. (Fig. 11.) The distal fibula was exposed, since exact reduction had not been achieved and soft tissue interposition was assumed to have occurred. The peroneal tendons were found lying between the fracture faces. They were removed and the fracture was reduced and held with a screw.

A full leg cast was applied and bivalved eight weeks after operation. Weight bearing was permitted four weeks later.

Four months after injury a moderate limp, mild swelling and limitation of motion were present but were subsiding.

SUMMARY

When the lower extremity is encased in a stockinette and suspended by the stockinette extending beyond the toes, the foot and ankle fall into adduction, internal rotation and supination.

The technic provides a useful adjunct to the management of abduction–external rotation fractures and injuries to the ligament of the ankle.

Three illustrative cases are presented.

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Vascular Changes Noted by Femoral Arteriography Following Operative Destruction of the Capsular and Periosteal Hip Vessels in Dogs

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THE treatment of hip fractures remains a particularly difficult problem. Intracapsular fractures, especially those of the subcapital type, have defied all methods of treatment to date and still result in a substantial percentage of non-union and aseptic necrosis of the femoral head.

If one could prognosticate which fractures will result in aseptic necrosis of the femoral head, it would then be possible to select rationally those patients with a fresh intracapsular fracture who would benefit from immediate replacement of the femoral head by metallic prosthesis. Several methods have been used in an attempt to determine those femoral heads due to undergo avascular necrosis. Venographic studies by Hulth [2] have provided approximately 80 per cent accuracy in prognosticating the eventual fate of the femoral head. Arteriographic studies by Mussbichler [4] and Rook [5] have demonstrated certain subtle changes in the smaller vessels surrounding the femoral head and neck. These changes heve been described in the branches of the medial circumflex artery and have been those of delayed filling and delayed emptying of these smaller branches (Fig. 1). In an effort to determine how hip injury affects the surrounding arterial patterns, arteriographic studies were performed in dogs. It was believed the anatomy [1] in the dog was sufficiently similar to the human being to be adequate for comparative study. Furthermore, it was believed that, if significant changes could be demonstrated about the dog's hip following destructive procedures, this study would be applicable to human beings as both Rook and Mussbichler have demonstrated previously that arteriography is safe and applicable as a routine procedure in studying hip fractures.

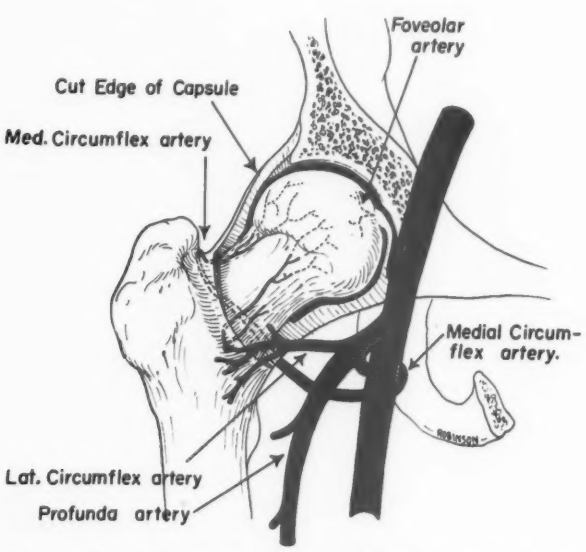

FIG. 1. This diagram illustrates the relationship of the hip capsule to the end vessels. Transcervical fractures which injure these end vessels may appreciably alter the femoral capital blood supply.

It was our aim to attempt to demonstrate "end vessels" and thereafter to show changes in them following their purposeful destruction. We were also interested in the changes in the vessels leading into these end vessels following their destruction. To carry out this study the normal arteriographic anatomy surrounding the hip joint was first determined by forty arteriograms on the intact canine hip. Destructive procedures about the hip joint were then

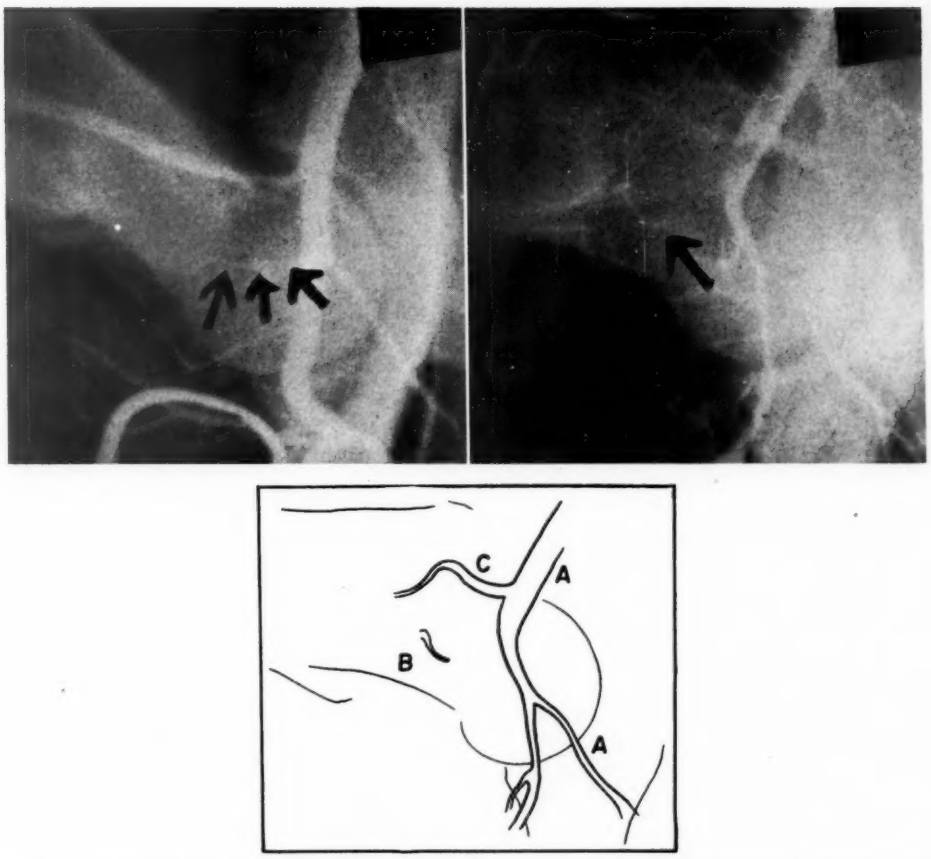

FIG. 2. Comparison of the preoperative and postoperative arteriograms demonstrate: A, decreased diameter; B, frank severance; and C, decreased vessel density. In this dog pericapsular division was performed.

performed and arteriograms again carried out to evaluate the radiographic changes which followed.

Normal mongrel dogs of varying sizes were studied. According to Ellenberger and Baam [1] the vasculature about the canine and the human hip joints are sufficiently similar to justify a preliminary study on dogs.

METHOD OF STUDY

Arteriographs taken of anesthetized normal mongrel dogs, employing a 75 per cent solution of Neo-iopax® or a 70 per cent solution of Urokon,® permitted demonstration of the networks of vessels which surround the hip. Following arteriography of the intact hips of twelve dogs, the hips were exposed by posterolateral incision and the joint capsules were incised circumferentially by sharp dissection. Transcervical osteotomy was then performed. (In one dog pericapsular division without osteotomy was performed.) Postoperative arteriograms were then compared to the preoperative films for vascular changes following the destructive procedure about the hip.

TECHNIQUE OF STUDY

Forty femoral arteriograms were taken of twelve dogs prior to carrying out any destructive surgical procedure on the hip joint. A longitudinal incision was carried down to the femoral artery which was exposed distal to the profundus femoral artery. A polyethylene catheter with an inside diameter of 0.034 inches and an outside diameter of 0.060 inches was threaded retrograde into the femoral artery for a distance of 3 cm. so that the injection to be made through it would fill the deep femoral, as well as the superficial femoral arteries. The femoral vessel distal to the joint of insertion of the polyethylene catheter was ligated with fine silk prior to arteriography. Ten cubic centimeters of contrast medium were injected through an ordinary Luer-lock syringe, the film being exposed as the last cubic centimeter of contrast medium was injected from the

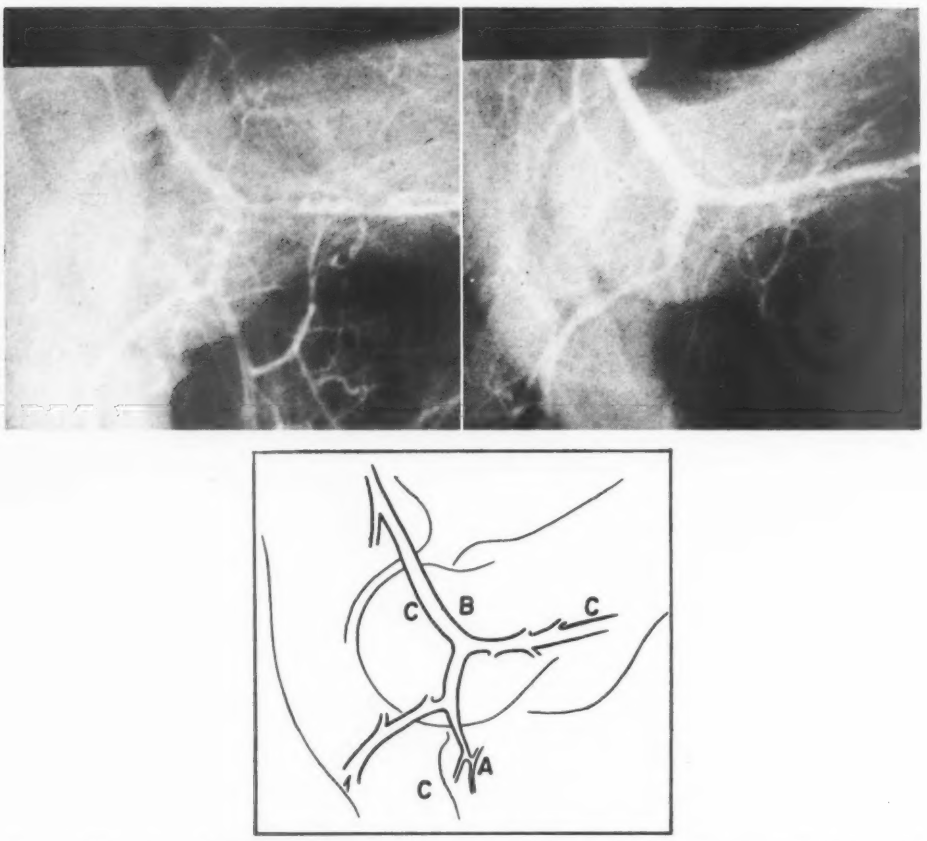

FIG. 3. Vascular changes demonstrated are: A, decreased vessel diameter; B, increased vessel diameter; and C, increased vessel density.

syringe into the polyethylene catheter. During arteriography, the dog's lower extremity was in the classical frog-leg position. Exposures with a portable x-ray machine were taken 1/20 second at a distance of 12 inches with 100 milliamperes and 60 kv.'s being employed. The film was developed over a five-minute period by normal techniques. Stereoscopic arteriograms carried out in two dogs failed to add to any information obtained and were abandoned. Wood's metal was used as a radiopaque contrast medium in two dogs [3] but proved unsuccessful in revealing the vascular details. Following preoperative arteriography in one dog, a posterolateral approach to the hip was carried out and the capsule was circumferentially divided by sharp dissection. In six dogs, capsular division was performed and the femoral neck was fractured transcervically with a sharp osteotome. The dog was again placed supinely in the frog leg position and repeat arteriograms were again carried out by the technique described in the discussion of the preoperative procedure.

OBSERVATIONS

In comparing the pre- and postoperative arteriograms it was found that: (1) the end vessels could not be demonstrated either before or after the operative procedure; (2) no significant changes in the smaller vessels surrounding the hip could be demonstrated following the destructive operative procedure; and (3) changes were noted in the larger vessels (i.e. vessels comparable to those leading into the end vessels) surrounding the hip. These changes were: increased vessel diameter, decreased vessel diameter, changes in vessel density, and frank severance. Figures 2 through 5 illustrate the vascular changes previously described.

COMMENTS

By arteriographic studies performed before and after destructive procedures about the hip joint, changes were demonstrated in vessel diameter and vessel density; frank severance of vessels and pooling of contrast medium were also occasionally demonstrated. At no time

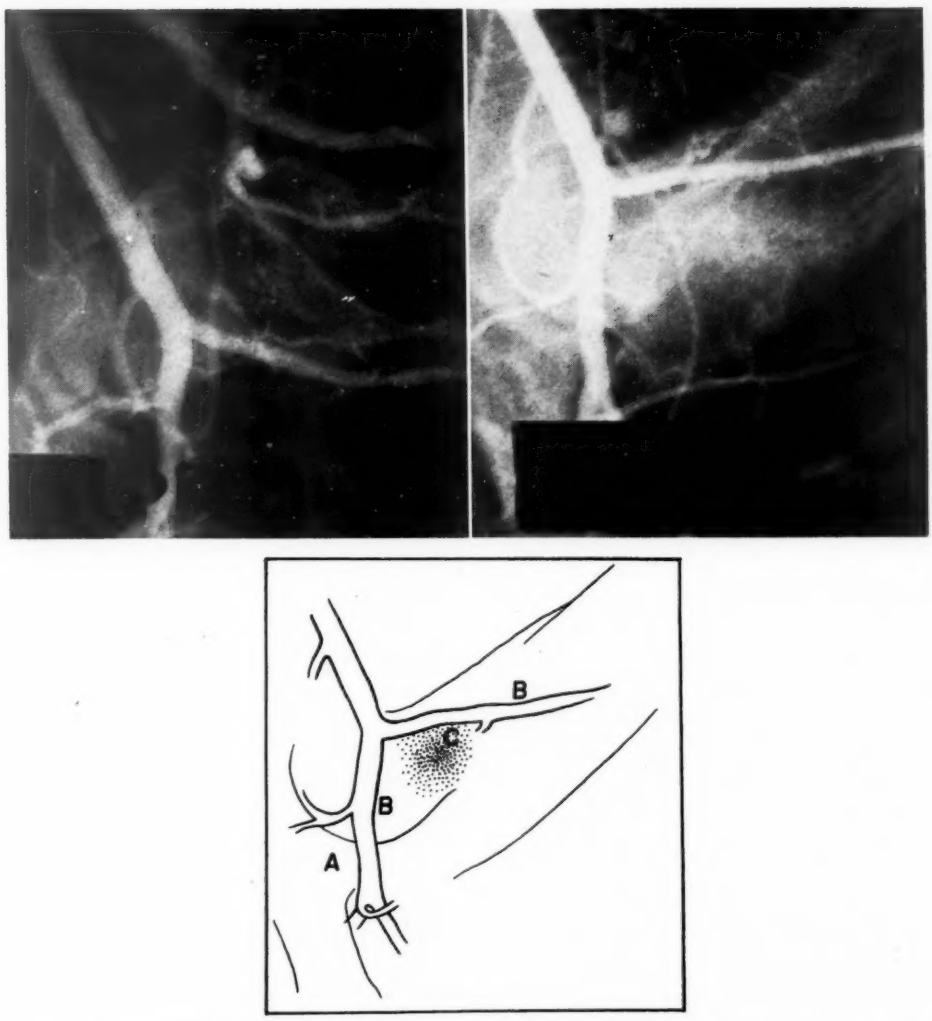

FIG. 4. Changes demonstrated are: A, decreased diameter: B, examples of increased vessel density; and C, frank severance of a vessel with resultant pooling of constrast medium.

were the end vessels in the femoral head revealed. The changes in the larger vessels following the destructive procedures about the hip were inconstant and may well be explained on the basis of artifact. The only definite change demonstrable in the vessels about the hip was frank severance. At no time was there evidence of arrested circulation in the intermediate or smaller vessels surrounding the hip.

It was significant that despite massive destructive procedures about the hip joint, only minimal arteriographic changes were demonstrable. This creates doubt in our minds concerning the validity of very subtle changes noted in human arteriographic studies following intracapsular fractures.

Despite the relatively negative findings in this study, it is believed that a trial of femoral arteriography in humans with careful follow-up is justified. More definitive information may be obtained by radio-isotope studies performed on the femoral head shortly following injury.

SUMMARY AND CONCLUSIONS

Arteriographic studies of the blood supply to the femoral neck and head were carried out before and after capsular and osteal division of the femoral neck. These arteriograms were compared to determine changes in the blood supply surrounding the hip joint.

Following purposeful destruction of the capsular and periosteal vessels in dogs, changes of the larger vessels surrounding the hip joint were of four types: changes in vessel diameter, changes in vessel density, frank severance of vessels and pooling of contrast medium.

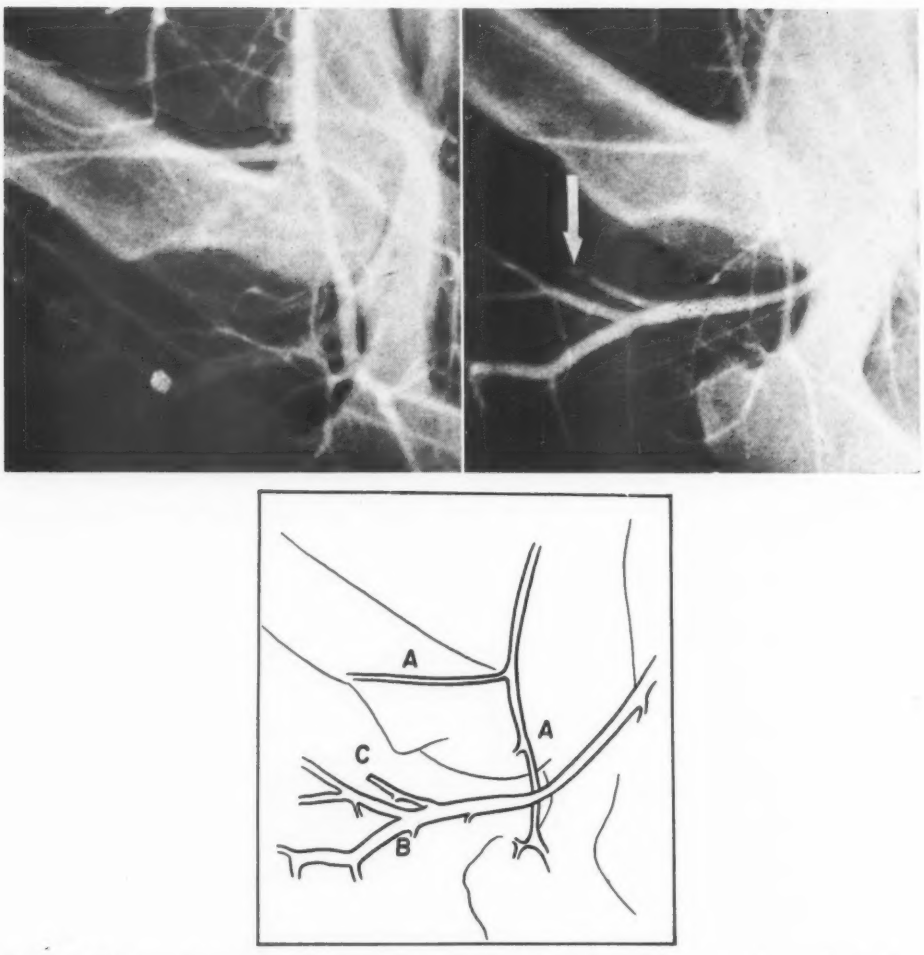

FIG. 5. Changes demonstrated are: A, decreased diameter; B, increased vessel density; and C, frank severance with no pooling of contrast medium.

It has not been possible to demonstrate the capsular and periosteal vessels of the hip in dogs by use of femoral arteriography.

Acknowledgment: We gratefully acknowledge the help and advice of Drs. Mary Ann Payne and Preston A. Wade.

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The Problem of the Supracondylar Fracture of the Femur in the Aged Person

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As a result of the rapidly increasing life expectancy, the treatment of the injured elderly patient is becoming a much more important consideration for those who are interested in the subject of trauma.

On the Combined Fracture Service of The New York Hospital–Hospital for Special Surgery, there has been a marked increase in the number of elderly people admitted. One of the striking findings has been the increase in the number of supracondylar fractures in those patients over sixty years of age. A study of our experience in these cases has given us a new approach to this very difficult problem, and we have learned some facts involving the etiology and treatment of these patients which we believe have helped us in their management.

To illustrate the findings and conclusions of our study, we are reporting on twenty-three consecutive cases.

Table 1 gives the age and sex incidence of these patients and charts the associated injuries occurring at the time of the accident, as well as the associated medical conditions which each patient exhibited. It is interesting to note, that of the twenty-three patients, eighteen were women and the majority were in their eighth decade. There were only five men, all of whom were in their seventh decade. Three had associated injuries, while only one woman had associated injuries, and these were minor, i.e. fracture of the rib and a fractured clavicle. The majority of the women had associated medical conditions but only two of the men had associated medical conditions.

Table II is an interesting record of the causes of the accidents resulting in the fracture. All eighteen female patients had minor accidents. In twelve cases, the history was "tripped" or "slipped and fell"; some patients fell out of bed, or out of a chair, or down stairs. The three men who had associated injuries were in major accidents; one was run over by a truck, another was struck by a car and the third fell into a

TABLE I
INCIDENCE AND ASSOCIATED CONDITIONS

Age	No. of Patients	Sex		Associated Injury (No. of Cases)		Associated Medical Condition (No. of Cases)	
		F	M	F	M	F	M
61–70	10	5	5	0	3	2	2
71–80	11	11	0	1	0	8	0
81–90	2	2	0	0	0	2	0
Total	..	18	5	1	3	12	2

TABLE II
CAUSE OF ACCIDENTS

Sex and Accident	No. of Cases
Female:	
Tripped, slipped or fell	12
Fell out of chair	3
Fell on stairs	2
Fell out of bed	1
Male:	
Slipped and fell	2
Run over by truck	1
Fell in pit	1
Struck by car	1

TABLE III

FACTORS PREDISPOSING TO FRACTURE

Case	Osteoporosis	Condition of Hip on Same Side As Fracture	Condition of Knee on Same Side As Fracture
I	Marked osteoporosis on x-ray examinations and at operation	.....	X-ray and long clinical history of osteoarthritis in both knees
II	Marked osteoporosis on x-ray examination	Comminuted intertrochanteric fracture 8 mo. prior to admission, treated with Smith-Petersen nail and plate	X-ray studies showed degenerative joint disease
III	Marked osteoporosis on x-ray examination	.....	.....
IV	Marked osteoporosis	.....	.....
V	Poliomyelitis in leg since infancy; marked osteoporosis on x-ray examination	.....	Surgical fusion of knee many yr. prior to admission for polio
VI	Marked osteoporosis on x-ray examination	Osteoarthritis on x-ray examination	X-ray and clinical evidence of osteoarthritis
VII	Man, age 69, no osteoporosis	.....	.....
VIII	Osteoporosis	.....	15 yr. history of arthritis in both knees
IX	Man, age 67, no osteoporosis	.....	.....
X	Osteoporosis	Fractured hip 29 yr. prior to admission, treated with spica; at time of admission patient had aseptic necrosis with varus deformity	.....
XI	Paget's disease	Paget's disease extending into femoral head	.....
XII	Marked osteoporosis on x-ray examination and autopsy	McMurray osteotomy performed for old fracture of femoral neck 5 yr. prior to admission, 74 days in spica; at autopsy non-union at hip fracture	.....
XIII	Osteoporosis	Intracapsular fracture treated with Moore nails 2 yr. prior to admission; 7 mo. later nails removed, non-union	Plateau fracture treated with plaster for 2 mo. 10 yr. prior to admission
XIV	Marked osteoporosis on x-ray examination and autopsy	Thompson replacement of the femoral head for severe osteoarthritis 1 yr. prior to admission	.....
XV	Osteoporosis	.....	Mid-calf amputation
XVI	Normal appearance of bones on x-ray examination	.....	Below-knee traumatic amputation with very long stump for many years prior to admission; 5 yr. prior to admission walking with crutches
XVII	Osteoporosis	.....	.....
XVIII	Marked osteoporosis on x-ray examination and at operation	.....	Plateau fracture treated with long leg cast 5 mo. prior to admission
XIX	Marked osteoporosis on x-ray examination	.....	X-ray and clinical evidence of marked osteoarthritis bilaterally
XX	Marked osteoporosis on x-ray examination and at operation	Walked with cane for severe osteoarthritis	Walked with cane for severe osteoarthritis
XXI	Man, age 69, no osteoporosis	.....	.....
XXII	Marked osteoporosis on x-ray examination	.....	X-ray evidence of advanced osteoarthritis
XXIII	Osteoporosis	Fracture of hip treated with Lorenzo screw and plate 3 yr. prior to admission	.....

deep pit. The two men who did not have associated injuries had minor falls and both had pre-existing disabilities of the limb.

The study of these cases (Table III) indicates that there were very definite predisposing factors to the fracture. A summary of the incidence of osteoporosis and previous joint disabilities in the patients studied discloses that every female patient showed evidence of osteoporosis (some very marked), but only one of the male patients showed evidence of osteoporosis. Fifteen of the eighteen women had previous joint disabilities of the hip or knee on the affected side and two of the five men had previous disabilities on the affected side.

FIG. 1. A seventy-eight year old woman with advanced rheumatoid arthritis and ankylosed knee joints fell from her wheel chair down a short flight of stairs sustaining bilateral supracondylar femoral fractures. There was little displacement and immobilization in plaster was effective in maintaining reduction.

PREDISPOSING FACTORS TO FRACTURE

Osteoporosis. The structure of the shaft of the femur in the elderly person is different than that of the normal, healthy young adult in that the apposition of new bone fails to keep pace with the normal osteoclastic resorption, and osteoporosis develops in old age because there is a general retardation of cellular proliferation. Replacement of the outlived osteocytes demands resorption of surrounding bone and this goes on while osteoblastic apposition of new bone fails. Thus the bony trabeculae become progressively thinner, fat content increases and the cortex becomes thin. The bone of the elderly person is therefore much more fragile than that of the normal, healthy young adult, and the thinness of the cortex makes it more susceptible to stresses, strains and leverage forces. Attempts to use internal fixation by means of metal screws, plates and rods are often made more difficult because of the fragility of the bone fragments immobilized, and often efforts at immobilization by means of intramedullary rods cause a shattering or splitting of the shaft of the bone. The thinning of the cortex causes an increase in the diameter of the intramedullary canal, and this adds to the difficulties in the attempted firm fixation by means of intramedullary rods. Whereas, in the young adult a 9 mm. rod fits snugly and firmly, in the elderly person the diameter of the canal at its narrowest point may measure 14, 15, or 16 mm.

Pre-existing Disabilities of the Hip and Knee. In the majority of cases as shown in Table III there was some evidence of a disability of either the hip or the knee or both of the limb on the same side. In five cases there had been a previous fracture of the hip on the same side with resulting disability. In one case there had been surgical fusion of the knee, and in two cases a fracture of the tibial plateau had been sustained previously followed by limitation of motion in the knee. In one case there had been traumatic amputation below the knee with limitation of motion in the knee; another patient had Paget's disease involving the femoral head and neck.

In all the women the injury was the result of minor trauma, a slip on a rug, a fall from a chair, stepping off a curb, and was not associated with the multiple injuries and severe shock which usually occur in this type of fracture in younger people. Three of the four male patients, all under seventy, suffered severe accidents with other multiple injuries.

Other Factors. There are other predisposing factors in fractures in this region which have to do with the weakness of the musculature of the patient, his inability to withstand sudden changes in position, and the awkwardness which the senile patient exhibits in attempting to prevent himself from falling when he is suddenly thrown off balance. The fact that many elderly patients see poorly and do not

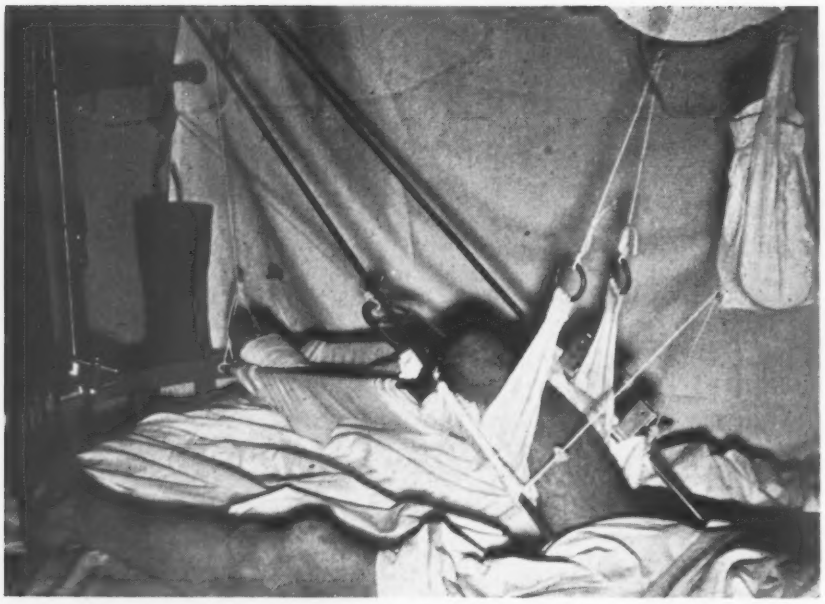

FIG. 2. Supracondylar fracture with posterior displacement of distal fragment. Skeletal traction applied to tibial tubercle. Posterior angulation corrected by sling under fracture site.

FIG. 3. Fracture pictured in Figure 2 before corrective sling.

hear well makes them much more apt to sustain injury.

OBJECTIVES

Fractures of the lower third of the femur involve not only the shaft of the bone but the knee joint as well and are therefore particularly difficult problems because they involve the consideration of several objectives, any one of which may interfere with the achievement of another.

The first and most important objective is, of course, the preservation of life. The serious complications which may result in elderly people are often difficult to prevent in the light of the various forms of treatment which are necessary in these cases. Many of these patients would not tolerate immobilization for a long period of time nor would they survive operative procedures. It is often difficult to prevent decubitus ulcers, pulmonary complications and other usual complications of this age period.

The elderly patient confined in plaster or confined to bed in traction may survive only a few days or weeks, and we know that the lowering of the mortality of patients with fractures of the hip has been in large measure due to the early ambulation allowed by the operative procedure of hip nailing. Any method which may allow early ambulation for these patients is desirable, and we therefore attempt to use internal fixation by means of intramedullary rods, angle plates and bolts whenever possible to allow the patient to be ambulatory. Sometimes these methods seem heroic but they are often life-saving. Because of the fragility of the fractured fragments, it is sometimes very difficult to maintain reduction by means of internal fixation, and the operative procedure is therefore of no avail in achieving the desired result of early ambulation. It is therefore necessary that the surgeon evaluate the situation carefully, and if in his judgment the operation must be followed by plaster immobilization, then operation may not be justified.

The second objective is the saving of the limb. Ordinarily, a fracture of the lower third of the femur does not threaten the viability of the limb but there are enough cases in which injury to the popliteal vessel results to make the surgeon always wary of this complication. The injury to the popliteal vessel, by reason of dislocation of the entire lower portion of the femur or posterior displacement of the sharp lower fragments, is usually indicated by a cold, pulseless foot and leg or by an increasing hematoma in the region of the popliteal vessels. On many occasions the reduction of the displaced fragment is alone enough to relieve pressure on the vessel and restore circulation to the limb, but in some instances when there is complete severance or severe laceration of the artery it is necessary to explore the area immediately and repair the vessel or perform a graft. Since the collateral circulation is often insufficient to preserve the limb when the popliteal vessel is divided, injuries to this vessel are best treated by excision of the damaged area and immediate grafting. In such instances it is often necessary to perform internal fixation of the fractured bone in order to immobilize the soft parts to assure healing of the grafted artery. If the patient's condition is good in such a case, it is advisable to attempt to save the limb by repair of the artery, but if he is in poor condition, it may be better to perform supracondylar amputation immediately in order to save his life.

FIG. 4. Same fracture as shown in Figure 3 after application of sling.

In any operative procedure on the lower extremity in an aged person, the use of a tourniquet is to be avoided even though the operation might be more easily performed in a bloodless field. The use of a tourniquet will almost surely cause interference with the circulation and interfere with healing of the wound and return of good function in the limb.

The third objective in the treatment of these fractures is the achieving of a stable, painless, weight-bearing limb as a result of firm bony union of the fracture. This, of course, involves in most instances long periods of immobilization because of the slow healing of the bones in this area. Although union may be assured in most instances, the bone becomes more demineralized and more brittle by reason of the immobilization superimposed on the injury and the limb becomes more susceptible to minor trauma. The postoperative care of these patients involves protection from minor falls and minor trauma, because of the fact that the longer the limb is immobilized the more osteoporotic it becomes. One of the advantages of an operative procedure which allows early ambulation and motion is that it will prevent some of the calcium loss.

The fourth and final objective and one closely bound up with the objective of healing,

FIG. 5. Shattered supracondylar femoral fracture sustained in patient with hip joint disability. Skeletal traction applied to lower femoral fragment with suspension in Braun-Böhler frame.

FIG. 6. Comminuted supracondylar fracture.

is the preservation of joint motion in the knee. This may be, in some instances, very difficult and often impossible to achieve because the bone must be firmly healed in order to allow weight bearing, and the motion in the joint may have to be sacrificed on occasion in order to achieve this objective. In the elderly patient the knee joint does not stand long immobilization well and stiffness is very apt to result. However, if there is no damage to the structures in the knee joint, one may expect to regain a considerable degree of motion in the joint. If there is injury to the joint structures by reason of the fracture itself or from operative trauma, the additional immobilization causes a marked restriction of motion.

TREATMENT

In many of the supracondylar fractures in the aged person, the displacement of the fragments is not great, particularly if there has been pre-existing stiffness or ankylosis of the

FIG. 7. Fracture shown in Figure 6 treated with wire traction through tibial tubercle with second wire traction through supracondylar region, controlling posterior angulation and displacement of lateral supracondylar fragment.

knee joint. In those cases in which the knee joint is already stiffened, it is unnecessary to consider the joint in treatment of the fracture and immobilization in plaster is usually the best method of treatment. (Fig. 1.) In these instances, the fractures usually heal well.

Skeletal traction, by means of a wire or pin through the tibial tubercle with the limb suspended in a Thomas splint or Böhler frame (Fig. 2) is the treatment of choice in many instances. The traction will reduce the fracture if care is taken to correct posterior angulation by means of a sling. (Figs. 3 and 4.) Skeletal traction applied only to the supracondylar region of the femur (Fig. 5) is not as satisfactory because the rotation of the lower fragments is more difficult to control than by traction through the tibial tubercle. Furthermore, infection of wire tracts more easily extends to the fracture area, a complication which is most serious. Occasionally it is necessary to apply a wire through the tibial tubercle and through the lower femoral fragment to prevent posterior angulation of the distal fragment. (Figs. 6 through 8.)

If there is shattering of the distal femur or an intercondylar fracture with displacement of the condyles, or if the distal fragment is displaced posteriorly (Figs. 9A and B), it may be impossible to reduce the fracture in any satisfactory position. In these cases neither

FIG. 8. Same case as shown in Figure 7 after removal of traction ten weeks later.

FIG. 9A. Comminuted supracondylar fracture with shattering of condyles and posterior displacement of distal fragment.

FIG. 9B. After open reduction with angle plate and bolt. Ten and a half month follow-up with resulting limitation of motion. Extension 178 degrees, flexion 100 degrees.

FIG. 10A. Comminuted transcondylar T fracture in woman of eighty-eight, with marked decalcification of femur.

FIG. 10B. After plate and bolt fixation. Distal fragment has displaced medially as bolt and large washer have pulled through lateral cortex of condyle.

traction nor plaster immobilization is successful. Internal fixation is then necessary to obtain reduction of the fragments. Even though the internal fixation will not be sufficiently firm to allow early motion at the knee joint due to the fragility of the bone or poor mechanical fixation, it is sometimes essential in spite of the necessity for external immobilization postoperatively.

TABLE IV
MORTALITY

Sex	No. of Cases	Deaths in Hospital	Deaths after 4 Mo.	Total Mortality (%)
Female..	18	3	3	33⅓
Male....	5	1	0	20

Table IV lists the mortality rate for both men and women and indicates that although the hospital mortality was low, many of these patients were transferred to nursing homes or to their homes while still immobilized in plaster and the mortality of 33⅓ per cent at the end

FIG. 11A. Typical supracondylar fracture.

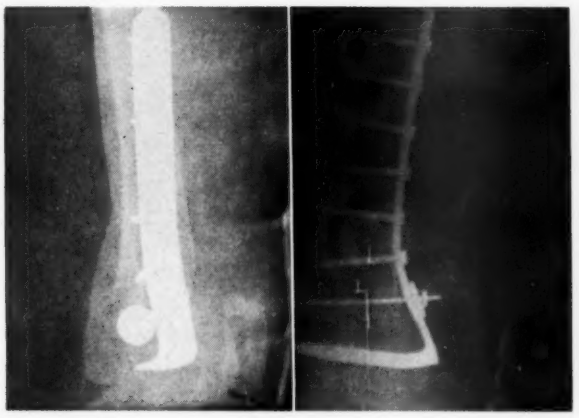

FIG. 11B. After immobilization with angle plate and bolt. Because of fragile cortex external immobilization with plaster is necessary. Bolt through distal fragment prevents rotation of condyles.

of four months should be considered the correct figure. There was practically no difference in the mortality of those patients treated by operation and those treated by closed methods.

We have found in our cases that the average number of days in plaster for patients treated surgically without associated complicating factors was seventy-two. (Table v.) Of twelve patients treated by open reduction, in only one case was external immobilization unnecessary after operation. In seven a spica was necessary, in three a long leg plaster, and in one, traction. Those patients treated by traction or plaster alone numbered eleven, and the average number of days of immobilization was seventy-eight.

It was discouraging to compare the hospitalization time for the patients treated by surgery and those treated by the closed method. (Table v.) Those patients treated by open operation averaged sixty days in the hospital while those treated by plaster or traction averaged only fifty days in the hospital. The mortality rate was about the same in both groups, and it would appear that the operative treatment has no advantages. However, when each patient is studied individually, it is found that in many of the operative cases it was thought the operation would be more suitable than long immobilization in plaster, and therefore these patients were sometimes in more serious condition than the patients treated by plaster alone. In the closed methods of treatment, reduction and application of plaster or the use of traction is preferable for those patients who can stand long periods of immobilization and in whom the fracture can be reduced and maintained.

In some instances in which the circulation of the limb is impaired or in which any prolonged treatment to secure reduction of the

TABLE V
IMMOBILIZATION AND HOSPITALIZATION

Procedure	No. of Cases	Days in Plaster	Days in Hospital
Operative	12	72	60
Closed	11	78	50

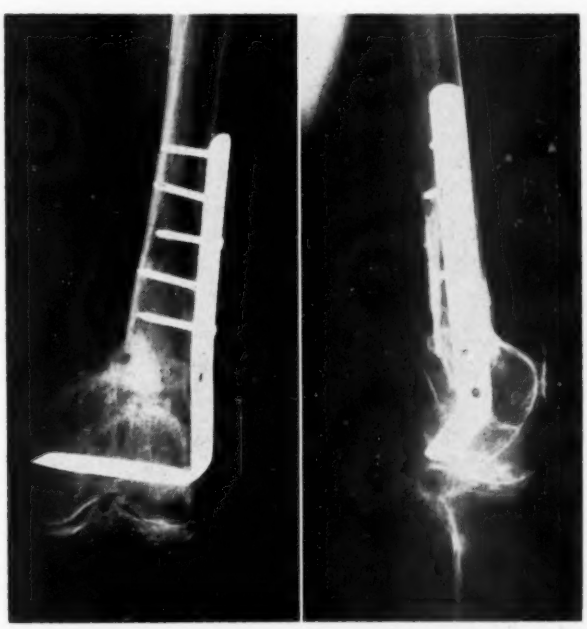

FIG. 12. Supracondylar fracture in eighty-five year old woman after fixation by Blount plate with resulting limitation of motion of knee joint.

FIG. 13A. Same case as shown in Figure 12. Fracture of femoral shaft sustained in fall over rug eighteen months later.

FIG. 13B. After removal of plate and screws and insertion of two Küntscher nails.

fracture might result in a fatality, primary supracondylar amputation is indicated.

Indications for Operation. Following are the indications for operation: (1) reduction impossible by closed means; (2) to hasten healing of the fracture; (3) to decrease the length of time of immobilization; and (4) to prevent stiffening of knee and ankle joint. In our experience the one definite indication for operation is in those cases when satisfactory position cannot

FIG. 14A. Multiple fracture of lower femoral shaft.

FIG. 14B. Immobilized with two nested Küntscher nails and encircling Parham bands.

FIG. 15A. Intercondylar fracture with loose medial condylar fragment.

FIG. 15B. Immobilized by bolt and single screw.

be achieved and maintained by any closed method.

There is little evidence to indicate that healing is more rapid by operative means although the appearance of callus on roentgenogram seemed to be seen earlier more consistently in the operative cases. This was probably due to the fact that the reduction was more satisfactory and the fragments were more securely immobilized by the use of internal fixation.

We have not found that the immobilization time has been materially decreased by use of internal fixation since so many patients need external immobilization in plaster due to the fragility of the fragments and to the inability of metallic fixation to hold the fragments well.

In those cases in which internal fixation allowed early removal of the plaster and motion of the knee, it is quite obvious that the motion in the knee joint is greatly improved.

Complications of Operation. The most important complication of operative intervention is infection. In the debilitated patient a long operative procedure with considerable surgical trauma and prolonged exposure of the wound may lead to infection. This complication is a very serious one and if it does not result in the necessity for amputation of the limb, it will most certainly hospitalize the patient for a long period and necessitate a long period of convalescence. Since many of these patients suffer from diabetes, cardiovascular disease and the like, their resistance to infection is sometimes poor. This must be taken into consideration when contemplating an operation.

Operations on the lower end of the femur often involve the knee joint itself, and in many instances the resulting stiffness from adhesion of the quadriceps may be the result of the operative procedure itself.

The fragility of the bone and thinness of the cortex of the femur may prevent good fixation of the screws and plates, and the fixative material may pull loose from the bony fragments causing the internal fixation to fail. When bolts or screws are applied to the shaft in the supracondylar region, it is wise to use large washers to prevent the screw or bolt from pulling

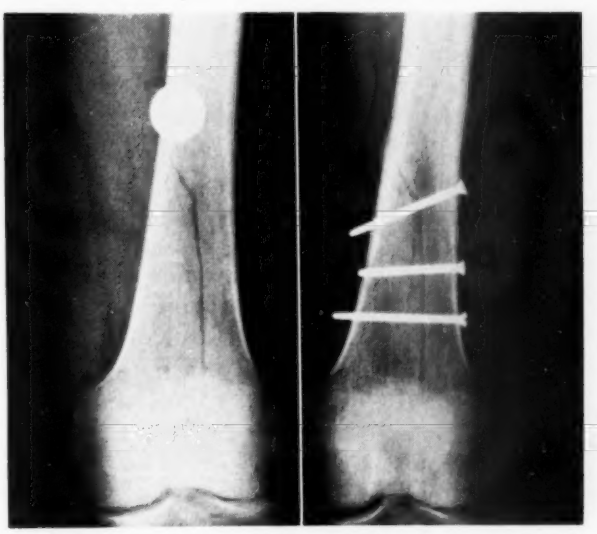

FIG. 16. *Left*, vertical intercondylar fracture. *Right*, internal fixation by multiple screws.

FIG. 17A. Eighty-eight year old woman eight months after supracondylar fracture with non-union.

FIG. 17B. Internal fixation achieved by Bosworth spline.

through the bone. (Fig. 10.) It is wise to take care in applying screws and bolts that they are applied firmly but not tightly since the threads easily tear through the thin cortex.

Methods of Internal Fixation. We believe the Austin-Moore type plate (Fig. 11) or the modified Blount blade plate (Fig. 12) are the most effective means of holding the usual supracondylar fracture in position. The disuse and immobilization necessary for the healing of these fractures makes the affected femur even more decalcified and brittle. The bone is particularly susceptible to the abnormal stresses and strains put upon it by the frequent limitation of knee motion and secondary fractures are prone to occur. (Figs. 13A and B.)

Occasionally for a higher oblique fracture, we have used a Küntscher nail with Parham bands (Figs. 14A and B), and on occasion we have used a bolt with a screw (Figs. 15A and B) or in one instance, screws alone. (Fig. 16.) We have used the Bosworth spline (Fig. 17) with considerable success in one instance in which the plate was applied to the lower fragment, and the spline inserted into the intramedullary canal of the proximal fragment.

We have not used the Rush nails through each condyle of the femur of the elderly patient because we have found in our few attempts that the cortex is too fragile and the nails do not maintain position.

SUMMARY

The supracondylar fracture in the aged person is usually sustained in the female patient with markedly decalcified femur, and is usually the result of a minor fall.

These fractures result from an unnatural leverage applied at the supracondylar area due to a predisposing knee or joint disability, or in many instances, disability of both joints.

These fractures present a very difficult problem in treatment since the patients do not stand long periods of immobilization well and operative methods are beset with complications.

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DISCUSSIONS

OSCAR PERRY HAMPTON, JR. (St. Louis, Mo.): It is a privilege to discuss this group of papers. Concern ng Dr. Quigley's paper and this ingenious method of his, I would appreciate his commenting further on the suffering caused in patients

who have their legs swung up with no mobilization for a period of twenty-four or forty-eight hours.

I particularly want to discuss Drs. Wade and Okinaka's paper because they were kind enough to let me read it ahead of time. We go along completely with their concept of an operative attack on a great many of these patients. We have not observed the extensive osteoporosis and weakening of the bone about which they commented. Perhaps we take better care of our older ladies out in the Middle West than they do in New York. At least, we apparently feed them better and their bones stay in better condition. Even in the illustrations Dr. Wade showed, I did not see so much osteoporosis. I would have thought that they would have used the operative attack for ts distinct advantages on most of those patients treated by non-operative methods.

With an "agonizing reappraisal," I have come to accept an idea of my younger associates, that a plaster cylinder will furnish adequate immobilization for one of these extremities after good internal fixation provided by a molded plate and screws, perhaps supplemented with other screws and occasionally with a Webb bolt across the condyles. With a plaster cylinder the patient may be handled more easily, may be turned in bed and helped into a chair without undue risk or discomfort. Certainly no stiffness of the ankle develops. Edema of the foot is avoided by elastic wrappings and elevation.

With the degree of fixation we have achieved, we have usually been able to discontinue using the cylinder at the end of six or, at the most, eight weeks. In some patients plaster immobilization was discontinued at the end of four weeks.

We attempt to have the blade portion cross the condyles and penetrate the opposite cortex. Actually, in a young person, but also in older people, our operative approach has been a lateral incision behind the vastus lateralis muscle. With T fractures we do not hesitate to extend the incision distally, turn it across beneath the patella, and sever the patellar ligament. This permits a large flap to be turned giving perfect exposure of the condyles.

This has permitted accurate fitting of the condyles, fixation with a Webb bolt, perhaps temporarily, and then fixation with the blade plate. In the patient in question the Webb bolt was removed immediately as it was no longer necessary.

An example of blade plate fixation of bilateral fractures is provided in the case of an eighty-eight year old woman. The plates were in our opinion too short but they happened to be all that were available in this particular institution at the time the patient came in. Fortunately they sufficed. The degree of fixation was adequate. She was immobilized by plaster cylinders for a period of only six weeks.

We have not had any of the fractures fall apart. In each instance the blade of the blade plate does perforate the far cortex.

I think it is important to discuss these problems because the comminuted condylar fractures of the femur in the aged person must be included among the unsolved fractures. I enjoyed all the papers.

HARRISON LLOYD MACLAUGHLIN (New York, N. Y.): I should like to endorse Dr. Francis' paper and commend to your consideration the advantages inherent in the prophylactic fixation of imminent metastatic fractures. I believe this is a very worthwhile contribution. I should also like to emphasize that, while I sponsored this paper, the implication that it came solely from The Presbyterian Hospital in New York is not entirely correct. A good bit of the work which went toward the formulation of Dr. Francis' paper was done at The Memorial Hospital, under the direction of Drs. Coley and Higinbotham.

I was very interested in the paper by Drs. McLeod and Braunstein because it corresponds to some work we have done. We have attacked this problem by injecting contrast media into the head of the femur and attempting to find an index of viability by intraosseous venograms. Our findings have, in general, corresponded to those of Drs. McLeod and Braunstein.

We have been unable to demonstrate a venous return from a fractured femoral head which has been displaced. Undisplaced impacted fractures show a normal venous circulation. Dislocations of the hip have revealed puddling of contrast media in the bone which persisted for several months, and finally (in those which escaped necrosis), a normal venous flow developed. Strangely enough, patients who in the operating room require a removal of the joint capsule, subsequently have shown a normal pattern of vascular return flow from the femoral head.

NICHOLAS JAMES GIANNESTRAS (Cincinnati, Ohio): I have been asked to discuss Dr. Quigley's paper and this I consider a pleasure and a privilege. I cannot agree with Dr. Hampton that these people suffer a tremendous amount of pain by being suspended with their toes and their feet up in the air following this type of an injury. After all, we do have sedative drugs.

I do know one thing, that Dr. Quigley's idea is a good one for treatment in instances such as those he brought out in which either the operative permit could not be procured or there was a large ulcer present. I did not get a chance to talk to Dr. Quigley to determine in the third case whether there were some extenuating circumstances which caused him to delay twelve hours.

I should like to ask him whether, in spite of the use of stockinet, any blistering of the skin developed in his patients? In some of these rather severe fractures of the ankle, no matter what type of pres-

sure bandage is applied, even when reduced immediately with stockinet and cast, one has to split the cast within a matter of twenty-four or forty-eight hours because of edema and one finds some blistering of the skin underneath the cast.

Another question I should like to ask is, in the postreduction films, why was the position of the foot in equinus? I am sure Dr. Quigley did not leave it that way, but those are little things that one must bring up because one cannot and must not completely agree with the author since this organization was built not on agreement but on disagreement (from the standpoint of discussion of papers).

I was very interested in Drs. McLeod and Braunstein's paper. I think that the statement the fine Dr. Kellogg Speed made many years ago, "The fate of the head is determined before the fracture," still stands.

T. B. Quigley (closing): With regard to Dr. Hampton's point, this naturally concerned us. These, indeed, are not rigidly immobilized ankles, but the fact of the matter is that they are in a sort of traction and patients in traction, as we all know, are comfortable when their fractures are reasonably well reduced. Splinting would defeat the purpose of the procedure.

The reason for delay in the operative treatment of the third patient was primarily gross edema which subsided very rapidly after suspension in stockinet.

In no patient thus far (and I do not understand this) have blisters developed. I think sooner or later we are probably going to find some blisters, but it is possible that the gentle compression of the stockinet does something to the skin to discourage their formation. As for immobilization in supination and internal rotation, this has not been a problem. The degree of inversion in which we have immobilized these people has not been as great as that recommended in the literature a generation or so ago.

It has been moderate and when the first cast change occurs, we have corrected it somewhat. We wind up with people without flat feet, so perhaps it is a good thing. The discussions have been most kind.

Paul W. Braunstein (closing): I want to thank Drs. McLaughlin and Giannestras for their fine remarks. Our venographic studies also carried out on human beings have reinforced our clinical opinion that in displaced fractures of the femoral neck there is usually puddling of the venographic material in the fracture site or in the intracapsular space and later avascular necrosis of the head develops. Those patients who have a demonstrable vessel in the venographic studies usually have no serious vascular injury, and most frequently progress to adequate healing of the fracture.

Preston A. Wade (closing): I want to thank Dr. Hampton for his remarks. Although he questioned the high incidence of decalcified fragile bone in our elderly patients and stated that his patients seemed to have more dense bones, I noticed in the one case he illustrated that the cortex was so thin it could barely be seen in the illustration. However, I must admit his patient showed excellent internal fixation of this difficult type of fracture.

We have had two cases in which the cortex was so thin and fragile that after internal fixation by blade, plate and bolt, the bolt head, washer and all, pulled through the cortex into the substance of the condyle, necessitating external immobilization in plaster.

We found internal fixation necessary in those cases in which the fracture was intercondylar with rotation of one condyle.

I would like to subscribe to the recommendations made by Dr. Francis in his fine paper. I like the idea of prophylactic internal fixation in those cases of metastatic involvement of long bones when pathological fracture is inevitable. We too operate on these patients and strangely enough we have noted in several cases that the involved area of the bone filled in with new bone after the operation, just as in the case Dr. Francis described.

Laryngeal Trauma and Its Complications

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LARYNGEAL trauma with the complications of acute respiratory obstruction may occur as an isolated injury or part of a multiple injury accident. Obstructing hematomas, dislocation and fractures of laryngeal cartilage result from direct trauma to the neck, in boxing, striking a protruding pipe or tree branch (or being struck by either), a blow from a baseball bat or golf ball, or falling while carrying a heavy object and striking its edge. Garroting or the entanglement of a scarf or necktie in machinery likewise produces collapse of the laryngeal cartilages. These cartilages maintain the patency of the airway and their destruction results in acute respiratory obstruction. Less severe injuries result in hoarseness, dysphonia or aphonia.

TABLE 1
ETIOLOGY OF EIGHTY-TWO CASES OF EXTERNAL LARYNGEAL TRAUMA

Mechanism of Injury	No. of Cases
Transportation vehicles (43 cases):	
Automobile	32
Streetcar, bus, train, bicycle, sled	7
Airplane	2
Tractor	2
Physical violence; sports (29 cases):	
Garroting, "strong arm," blow by edge of hand	6
Gunshot	9
Cutthroat	5
Boxing	6
Golf ball, baseball	3
Industrial (10 cases):	
Lumber yard, striking projecting machinery, falling on heavy object being carried	7
Elevator doors or window closing on neck	3
Total	82

Automobile accidents are responsible for most of the multiple injury accidents in which the larynx is involved. The injury almost invariably occurs to the passenger in the front seat whose extended neck strikes the dashboard as the head is thrown forward through the windshield. The accident may occur to a passenger in the rear seat who is thrown forward against the back of the front seat or to a streetcar passenger whose neck strikes the pipe-like handle on the seat in front of him if the car stops suddenly or is involved in a head-on accident. A similar injury may occur to the pilot or copilot of a small plane in a rough or crash landing. For the passenger in the front seat of an automobile, some measure of protection is afforded by a safety belt and a heavy foam-rubber pad over the dashboard [*1*]; but while these suggestions are recommended by those attempting to reduce the morbidity and mortality from auto accidents, few heed this advice.

REPORT OF CASES

In this report, only cases of external trauma are reviewed. Cases of internal trauma such as caustic burns of the larynx associated with the ingestion of lye [*2*], surgical trauma [*3*], intubation injuries [*4*], feeding-tube accidents [*5*], paralysis of the larynx following thyroidectomy, and trauma due to vocal abuse are not included.

This report is based on eighty-two cases of external trauma to the larynx seen during the past ten years. A statistical analysis of the etiologic factors is given in Table 1. While the majority of those injured were males, half of those with laryngeal injuries incurred in automobile accidents were women. This is due to the fact that this injury is typically a "front-seat passenger" injury.

SYMPTOMS AND DIAGNOSIS

An abnormal or absent voice following a history of trauma is fairly indicative of some

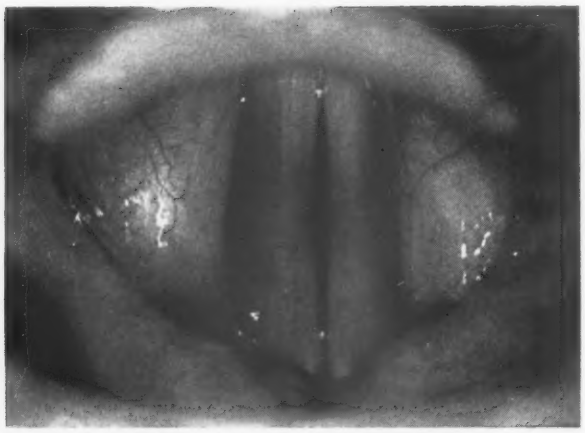

FIG. 1. Mirror view of the normal larynx.

FIG. 2. Mirror view of a larynx which sustained a compression fracture in an automobile accident. The epiglottis is pushed posteriorly, the aryepiglottic folds flattened, the arytenoids are dislocated and the cords are replaced by an obstructing mass of scar tissue.

degree of soft tissue or cartilaginous involvement of the larynx. However, a cerebral injury incurred in an accident could cause a voice change without direct laryngeal involvement; therefore, this possibliity also must be considered. Voice changes may be immediate and may range from variations in pitch and volume to total aphonia. Respiratory symptoms are progressive stridor, prolonged noisy inspiration and expiration, dyspnea, supra- and infrasternal retractions and mental changes associated with acute or progressive chronic anoxemia.

Palpation of the neck in suspected laryngeal trauma may disclose deformity, discoloration, abnormal movement or fixation of the thyroid or cricoid cartilages, or the supporting thyroihyoid membrane. Quite commonly in traumatic fractures of the larynx the thyroid cartilage is flattened or one ala is found to overlap the other anteriorly. In recent injuries, crepitation and abnormal fixation and induration suggest deformity sufficient to cause stenosis.

X-ray studies of the larynx, even in the infant, are of inestimable value when laryngeal trauma is suspected, not alone for diagnosis but for record and subsequent progress studies. Lateral x-ray studies of the neck for soft tissues often suffice, but in questionable cases or for more detailed study the anteroposterior intraesophageal film studies as well as planographic studies are indicated. The injection of opaque media such as Lipiodol is occasionally helpful. Mirror and direct laryngoscopic photography provides a chronological record of treatment as well as a means of making "before and after" comparisons. (Figs. 1 and 2.)

Final evaluation of the general configuration, the location, degree and extent of a laryngeal injury must be made by direct laryngoscopic and tracheoscopic examinations. For this purpose, a smooth-tipped laryngoscope and tracheoscope is used to permit introduction of the instrument through the glottis and into the usually distorted subglottic area and finally into the trachea. In case of severe stenosis or total atresia, examination may be successfully made with the child- or even infant-sized bronchoscope introduced through the mouth or from below upward through the tracheostomy.

TREATMENT

The therapy of laryngeal trauma must be guided by the extent of injury. If soft tissues alone are involved by an obstructing hematoma, voice rest (silence) and steam inhalations are essential. Low tracheostomy should be performed before it becomes a desperate emergency if obstruction is present on the initial examination of the patient or if dyspnea is becoming progressively more severe. Dysphagia will undoubtedly be a complication in this type of trauma but the use of a feeding tube is to be avoided because of the ulceration that it may cause in the mucosa of the laryngopharynx.

Severe compressing injuries such as acute injuries to the larynx resulting from automobile accidents require as active a therapeutic regimen as would be employed in a crushing injury of the nose. (Fig. 3.) Broken cartilages must be replaced, the airway re-established and a splint must be introduced to maintain the position of the replaced cartilages until healing is effected. Emergency tracheotomy is life-saving when the

FIG. 3. Cervical emphysema and laryngeal deformity following an automobile accident.

FIG. 4. Intralaryngeal splint inserted to maintain position of replaced cartilages, insuring an airway after healing. Early reduction of laryngeal fractures is as essential as early reduction of any other fracture.

accident has occurred and the compressed laryngeal structures occlude the airway. It is extremely important that the tracheotomy be placed low, as far from the fractured larynx as possible to avoid loss of the cricoid through further trauma and infection. The active measures that should be undertaken early should restore and maintain the fractured cartilages as close to their original position as possible, as soon after the accident as is permitted by the general condition of the patient. Peroral manipulation with forceps or the tip of a laryngoscope may suffice in some cases to re-establish the airway. In other cases immediate open reduction may be required to obtain satisfactory realignment of cartilages. Following either procedure, a polyethylene or similar tube may be inserted into the glottis to serve as a splint to support the soft tissues until healing takes place. (Fig. 4.)

It is unfortunate that often in a multiple injury accident in which the laryngeal fracture seems but a minor or unimportant complication, after the airway has been satisfactorily established by the tracheotomy the larynx is left untreated. Often the associated jaw and sternal fractures, internal injuries and fractures of the extremities take precedence in therapeutic importance. The larynx is understandably difficult to reach under these circumstances. Nevertheless, it is essential that fracture-reducing procedures be instituted within the first few days following the accident before the cartilages have become fixed in their compressed, obstructing position, and before scar tissue forms in the accompanying hematoma to further contract or even completely obliterate the airway. These procedures are too often delayed in the hope that as swelling subsides the airway will return to an adequate size. This does not occur unless the trauma has been minimal and unaccompanied by fracture dislocation of the cartilaginous framework of the larynx.

COMPLICATIONS

Severe laryngeal trauma that is not treated by early replacement and fixation of fractured

or dislocated cartilages progresses to chronic laryngeal stenosis with a distressing degree of disability. Physical impairment ranges from respiratory effort, stridor and even chronic anoxemia, to actual acute obstruction which may have to be relieved mechanically by tracheotomy. Mentally, the disability is aggravated by the annoyance of the tracheotomy tube and the psychic stress of an abnormal, peculiar voice which is a constant source of embarrassment. This continues far beyond the first contact with others; children so afflicted are subject to teasing and insults from their playmates and adults have difficulty not only socially but in finding or keeping steady employment.

Rehabilitation of the patient with chronic laryngeal stenosis has three requisites: first, reestablishment of the normal airway and closure of the tracheotomy; second, the restoration of as serviceable a voice as possible, and assisting the patient in overcoming the embarrassment of what is frequently exceedingly abnormal speech; third, the provision of a larynx that will close satisfactorily to prevent the aspiration of food and fluids during deglutition.

The management of chronic laryngeal stenosis that has resulted from laryngeal trauma depends on the degree of respiratory impairment and the nature of the impairment. The treatment of some cases is effectively accomplished by simple endoscopic dilatations with bougies, intralaryngeal rubber or acrylic molds. However, surgical reconstruction of the completely stenosed larynx becomes necessary when the lumen is obliterated and the configuration of the supporting cartilages has been destroyed by the trauma or subsequent infection.

Thirty-three patients with chronic laryngeal stenosis following external laryngeal trauma have been seen who have required surgical procedures for restoration of the airway. Some responded to simple intralaryngeal bougienage while others required the use of an indwelling rubber, polyethylene or acrylic mold. Such severe deforming stenosis or atresia developed in thirteen patients that total reconstruction of the laryngeal airway became necessary. Such reconstruction of the larynx is long and tedious and requires numerous external as well as endoscopic surgical procedures. Proper early management would, in most cases, avoid the necessity of this procedure.

The surgical steps are begun only after evidence of perichondritis has disappeared and all methods have been used to eliminate residues of infection. The larynx is then opened, and deformed and obstructing cartilage and scar tissue are removed. This often necessitates removal of most of the tissue within the larynx. Employing a stent graft, the interior of the larynx is lined with skin and subsequently the lumen is maintained by an acrylic or polyethylene mold attached to the tracheotomy tube and maintained in position for six to nine months. After its removal and after the patency of the airway has been determined for an adequate test period, the tracheotomy tube may be removed and the tracheostomy closed. Important details of this technic have been published elsewhere [3]. Of the thirteen patients with laryngeal atresia or chronic laryngeal stenosis thus treated, ten have had a satisfactory restoration of respiratory function through the larynx and closure of the tracheostomy. Two are still undergoing treatment with the polyethylene molds in place attached to their tracheotomy tubes. The thirteenth patient has a serviceable voice and an adequate airway, but although she can eat solids and semi-solids without difficulty she aspirates liquids in attempting to drink. Control of this aspect of deglutition is improving.

All patients with voice changes following laryngeal trauma are referred to the Division of Speech for study, voice recording and instruction. Improvement in vocal function is obtained through the determination of the most efficient utilization of remaining pharyngeal and laryngeal muscles or scar tissue bands. Physical as well as psychologic benefits are very apparent in these patients. Through group lessons they are in contact with others who have difficulty in expression similar to their own. Practice, instruction and the utilization of group training constitutes a rehabilitation program for patients who have suffered laryngeal trauma that is essential in restoring maximum function.

SUMMARY

1. A review of eighty-two patients who sustained external trauma to the larynx shows the commonest cause to be automobile and other vehicular accidents (forty-three cases). Other vehicular accidents involved streetcars, buses, trains, airplanes, a tractor, bicycle and sled. In the automobile accidents the laryngeal

injury was usually one of multiple injuries and it occurred as frequently in females as in males.

2. Next in frequency as a cause of laryngeal trauma is physical violence (twenty-nine cases), i.e. garroting, "strong arm," blow by edge of hand, gunshot, cutthroat, boxing and being struck by a baseball or golf ball. Twenty-seven of this group were males, only two females.

3. Ten patients, all men, received their laryngeal injuries in industrial accidents, being struck in the neck by a "two by four," striking projecting machinery or falling while carrying a heavy object and striking an edge of it in the fall. Three men had put their heads through open windows or horizontal elevator doors, the doors or windows closing on the neck.

4. Minimal injuries cause hoarseness, dysphonia and aphonia. The pathologic conditions included hematomas, lacerations of the cords or other soft tissues, and dislocations or fractures of laryngeal cartilages. Respiratory obstruction is evidence of more severe injury and may vary in degree from slight respiratory embarrassment to total atresia and asphyxia.

5. Diagnosis is established by palpation, mirror and direct laryngoscopic examinations of the larynx and x-ray films of the neck, particularly the lateral view.

6. Treatment of minimal injuries consists of hot packs, voice rest (silence) and steam inhalations, with voice rehabilitation to help restore this important laryngeal function after the acute manifestations have subsided.

7. Severe injuries to the larynx require low tracheotomy to establish the airway. Then, as soon as the patient's general condition will permit, broken cartilages must be replaced and held in position by an intralaryngeal splint or mold to insure an adequate airway. If manipulation perorally cannot be accomplished because of an associated fractured jaw, this must be performed through the tracheostomy or by external, open reduction.

8. Failure or inadequate early management results in chronic laryngeal stenosis and the need of a permanent tracheostomy. Treatment of this complication requires reconstruction of the laryngeal lumen through the removal of scar and deformed cartilage and the lining of the interior of the larynx with a split thickness skin graft. This long and tedious process can be avoided by early reduction and fixation of the laryngeal fractures.

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Traumatic Diplopia

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FRACTURES of the facial bones may be classified into two main groups: first, the Le Fort type in which the force meets the face straight on, most commonly across the bridge of the nose (Figs. 1 and 2); and second, those in which the force strikes obliquely on the zygomatic bone. (Fig. 3.)

In the first group the fracture, while presenting varied forms and complications, usually follows the suture line between the frontal bone above, and the nasal bone, frontal process of maxilla, lacrimal and ethmoid bones below, to reach the sphenoid about the optic foramen. It then passes down and forward to merge with the inferior orbital fissure. Leaving the fissure anteriorly, it crosses the frontal process of zygomatic bone into the temporal fossa. The zygomatic process of temporal bone fractures near its suture line with zygoma.

Inferiorly the fracture line passes through the pterygoid plates to the midline. With the force following the same course on the other side, the fracture ring is complete and the whole bony structure of the face floats free.

Although this type of fracture results in cosmetic deformity, it has not, in our experience, because of its relative symmetry produced ocular imbalance.

The second type of fracture, in which the force meets the zygomatic eminence, is more common. Rowe and Killey [1] describe twelve variations. In its simplest form, the zygoma is crushed like an egg tapped with a spoon. However, when the force is directed from slightly above the horizontal, the fracture line extends across the base of the flaring buttress of the zygomatic eminence up to the rim of the orbit, often passing through the infraorbital foramen, posteriorly along the infraorbital plate between ethmoid and maxilla, anteriorly along the inferior orbital fissure and across the zygomatic bone. The infraorbital margin is driven down and backward and the infraorbital plate with it. This not only allows the eyeball to drop down and back, it encourages it to do so by displacing the attachment of the inferior oblique muscle and possibly of the inferior rectus as well. The result is diplopia.

The victim of injuries to the facial bones is most often found in the automobile. Commonly he is sitting in the right hand front seat and has been thrust against windshield or dashboard. The upper rim of the steering wheel can offer the same resistance to the driver, or the back of the front seat to a back seat passenger. The victim's injuries are often multiple and others may present more acute danger than those of the face.

The patient with cerebral concussion cannot give a clinical history of diplopia; the patient with a smashed chest or pelvis may be too miserable to mention it or even to be aware of seeing double. On examination, the soft tissue contusion over a flattened zygomatic bone may be enough to preserve the normal skin contour and the symmetry of the face.

It follows that examination of any patient with facial contusions or lacerations is not complete until he has been questioned about diplopia and x-ray studies have been made.

If diplopia is present, bony displacement about the orbit must be considered as the prime cause. I believe that although diplopia in a patient looking to the peripheries of the visual field may be due to traumatic muscular imbalance which can be transient, diplopia in a patient looking straight ahead (discovered on examination before there is marked soft tissue swelling) is always due to displacement of the eyeball secondary to traumatic deformity of the orbit.

The ideal time for reduction of a fractured zygomatic bone, with or without involvement of the infraorbital plate, is on the fourth or fifth

FIG. 1. The type of fracture resulting most commonly when force meets the face straight on.

FIG. 2. Another view of the type of fracture shown in Figure 1.

day after the accident. After this, beginning bony union which is rapid in this area may make reduction difficult. Earlier, there is not sufficient organization of the hematoma to hold the fragments in place once they are reduced.

For the reduction I still like the combined approach I described some years ago [2]. (Fig. 3.) Incision is through the mouth along the superior sulcus, posteriorly from the second bicuspid. This will expose the fracture line in the maxilla across the base of the zygomatic eminence, and the antrum can be entered on levering it up slightly with a director. By blunt dissection the second director is introduced beneath the zygomatic arch. These two levers are manipulated to bring the bony fragment, consisting of zygoma, maxilla and infraorbital plate, up into position. To me, this seems a more workable approach than the Gillies' temporal route.

Palpation along the infraorbital margins is the best guide to reduction but a further check can be made by using two long directors. These are so placed that each rests below on the small, anatomically nameless depression lateral to the nasolacrimal canal, and above on the notch of the supraorbital foramen. The long lever shows in exaggerated form a minute depression of the exopthalmometer which will detect the least posterior displacement.

If the reduction will not maintain itself and particularly if there be a fracture running back through the center of the infraorbital plate from the infraorbital margin, the antrum must be packed with gauze, bringing the end out through the nares for later removal. Postoperatively, a head band made of adhesive plaster with large corks projecting from it like a diadem is worn askew to the injured side of the face.

Good reduction of the fracture is followed as a matter of course by correction of the diplopia.

Correction of diplopia in the patient in whom bony union has already occurred, presents a more difficult problem. This situation results from failure to recognize the disability in the early stage when the fracture is reducible, de-

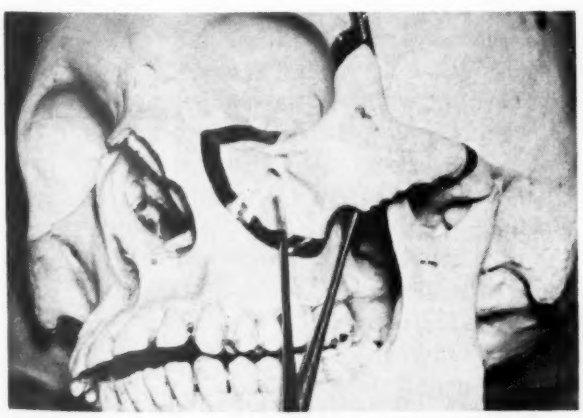

FIG. 3. Fracture resulting from a force against the zygomatic bone. The elevators are placed for reduction. The anterior is within the antrum and they may be manipulated together.

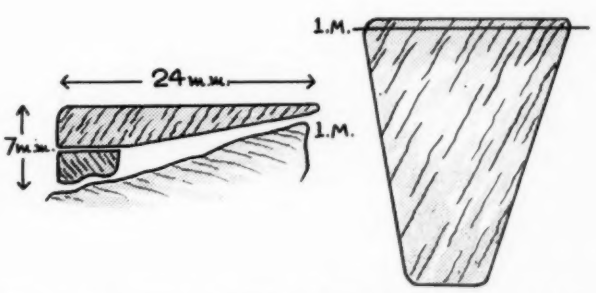

FIG. 4. Diagram of the graft, from above and in section, resting on the infraorbital plate.

FIG. 5. The graft is seen in this planograph as an increased density on the infraorbital plate.

FIG. 6. Six months after operation, this patient reports continuing improvement in the diplopia at the peripheries of his visual fields which was not completely corrected by the graft. The nasal fracture was from a previous injury.

lay in treatment because of other, serious injuries, or the failure of early treatment to correct the diplopia completely.

The most direct way to reduce the ptosis of the eye is to free the displaced fragment approximately along its old fracture lines and put it back where it was. The difficulty is in holding it there against the pressure of the intraorbital soft tissues which have become fixed in their abnormal positions. Even wired together and further supported by guy wires from a plaster head cap, the sharply cut bone edges make for instability.

Restoration of the orbital floor by graft is a simpler operation and offers, I believe, greater opportunity for accuracy in correcting the ptosis. As a graft, bone has the great advantage over cartilage of holding the shape and position in which the surgeon forms and places it.

The first and perhaps most important stage of the treatment is the accurate assessment, in millimeters, of the defect. The exopthalmometer, designed for measuring protrusion of the eyeball, serves equally as well as an enopthalmometer to measure the posterior displacement of the pupil. Posterior displacement, in itself, does not seem to cause diplopia but measurement of it helps in planning the repair.

Roentgenograms and planographs can be taken almost distortion free and measurement of the posterior and inferior displacement of the orbital plate is made from them. In the case illustrated herein, the posterior displacement of the eyeball as measured by the exopthalmometer was 8 mm. The posterior displacement of the infraorbital margin, as estimated on anteroposterior and lateral skull films, was 2 to 4 mm. and the downward displacement, 2 mm. From these films and planographs the infraorbital plate was found to be depressed 7 mm. at a depth of 2.5 cm. from the normal infraorbital margin.

It followed that the new infraorbital plate should project 2 to 4 mm. beyond the depressed one, be 2 mm. higher at the level of the depressed infraorbital margin, and 7 mm. higher at the depth of 2.5 cm.

The cutting of such a graft becomes a fairly simple, if meticulous, geometrical problem.

With the patient under general anesthesia a contour incision is made in the inferior palpebral

fold. The periosteum is incised along the infraorbital margin and elevated well back along the infraorbital plate. It comes up easily. However, if the case be one of long standing the optic nerve has shortened, the ocular muscles have shortened and slow, gentle dissection must be carried out in an effort to mobilize these structures to the point at which they will permit the eyeball to come forward.

The width of the infraorbital plate is measured and (remembering that it narrows as it extends back and that the graft must not lie over the inferior orbital fissure), it is cut from the inner surface of the iliac crest just lateral to the anterior superior spine to the measurements previously determined. This graft will probably be too thick on its posterior margin to insert without risk of damage to the eyeball. (Fig. 4.) On its horizontal plane it is cut into two parts. The superior portion is inserted first and fitted so that it rests without teetering along the infraorbital margin. The inferior portion is then inserted and carried back to its original position along the posterior margin of the graft. The periosteum should hold the graft snugly in place and if the dissection of the soft tissue has been adequate, pressure on the eyeball should not be great enough to produce flattening. The orbicularis oculi muscle is drawn over the graft and the skin is closed.

On cutting the graft some extra pieces of bone are taken and stored in saline for possible secondary adjustments.

The success of the operation depends not on whether the patient has a perfect cosmetic or geometric result but on whether or not he has binocular vision. It is therefore important for the surgeon to see him as soon as he has wakened. On questioning, the patient whose roentgenograms are shown was satisfied that the diplopia was gone. The next day he was not so sure and for the next five days was quite despondent because the postoperative swelling within the orbit produced so much distortion that his diplopia was at least as bad as ever. Then the swelling subsided and binocular vision returned.

If immediately after operation the patient does not have binocular vision, he should be re-examined, undergo x-ray studies and be returned to the operating room, with the extra pieces of bone, in an attempt to improve the position of the eyeball.

I claim no wide experience with this operation but submit it as a simpler and surer procedure than reduction of the depressed infraorbital plate by operative refracture and elevation. Our results have not been cosmetically or geometrically perfect but they have been good enough to give the patient binocular vision on looking straight ahead. (Figs. 5 and 6.) The patient still has 5 mm. posterior displacement of his eyeball but he does his work as a machinist with good binocular vision, whereas for the three months between the time of his injury and his grafting operation he wore a patch over the eye at all times.

The responsibility for the correction of traumatic diplopia does not lie primarily with the opthalmologist but with the surgeon, whether he be a general, orthopedic or neurosurgeon, who first treats the patient. The displacement of a fractured zygomatic bone can be slight; the lasting disability of traumatic diplopia, unrecognized at the proper time and untreated, can be tremendous. I have seen many a patient, the victim of multiple injuries, saved from death by courageous and determined surgical care only to suffer through the rest of his days from the disability of a wound considered too minor to bother with at the time of his crisis. As medical practitioners it is our duty not only to save life but to make it worth while.

SUMMARY

A depressed fracture of the zygoma not rarely produces diplopia by displacing the eye. In every case of facial injury, this complication must be looked for early when correction is relatively simple.

If diplopia is present after the facial fractures have united, bone graft on the orbital floor is recommended rather than refracture and restoration of the fragments.

The grafting operation is simple but requires meticulous technique.

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The Fallacy of the Term "Whiplash Injury"

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IN recent years the term "whiplash injury" has become deeply ingrained in the vocabulary of the lawyer and physician. It has been used to describe a syndrome ill-defined, loosely utilized and poorly documented. Although the syndrome is voluminously reported upon in the medical literature, there are widely differing opinions as to its magnitude. In an attempt to bring this aspect of the problem into proper focus, epidemiological studies concerning this syndrome are presented.

At the time this study was initiated, the records of the Automotive Crash Injury project at Cornell University Medical College contained documented medical findings on 12,764 occupants in 5,710 automobiles involved in accidents causing injury. The general outline of the medical aspects of injuries in automobile accidents has been presented in a previous publication [1]. By these studies the incidence and degree of severity of injury to the neck were reported. Now with an even greater injury experience available for analysis there is enough material to study incidence and severity of the whiplash syndrome.

REVIEW OF LITERATURE

The term whiplash has become more prevalent in medical publications. It has been defined in many different ways. The majority of authors agree that such injury is usually associated with unwarned impact to the rear of the vehicle. Some [2–4] describe this injury as primary cervical flexion followed by extension, while others [5,9] hold that the reverse is true. All authors describe whiplash as an injury while actually they are describing the kinematic behavior of the head and neck rather than a true anatomical or pathological entity sustained at the time of deceleration. This behavior pattern experienced by the head and neck in an automobile accident has, with increasing frequency, been listed as a diagnosis rather than a cause of injury. Too often a true clinical or anatomical diagnosis of cervical injury has been sacrificed for the "catchall" phrase whiplash injury. True injury, such as demonstrable fracture or dislocation, is so described in many of the cases reported while in others it is described only as whiplash or "symptomatic injuries." The majority of reports on the subject review between ten and 100 examples of whiplash injury. There is a paucity of clear-cut information correlating accident details with injury production—this being an obvious shortcoming in questioning a patient involved in any such frightening experience.

The time of onset of symptoms as reported in the literature reviewed has varied markedly. It is significant that in concomitant injuries, which the patients described, symptoms were immediately manifest while in many cervical injuries complaints were unrecorded until a relatively long period after the accident. The delayed onset of symptoms about the neck in comparison with the immediate recognition of symptoms in other areas of the body may suggest that in the elapsed time interval between accident and examination, other stimuli have developed which create an awareness of the injury pattern (litigation, etc.). In almost all severe injuries, cervical pain, dysfunction and disability were quickly evident. The lesser injuries frequently went unnoticed with the coexistence of other more serious injuries to body areas. Lipow [6] noted the conscious or subconscious realization of pain with the passage of time after the accident and believed even malingering frequently occurred. In any event, onset of symptoms seems to be delayed

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in the minor cases of whiplash and more immediate in those in which there are demonstrable physical or roentgenographic findings.

In almost all the articles reviewed in the literature the incidence of over-all injury has not been described in those patients with cervical pain and disability. Because the number of cases studied was small or selected, it is believed that many of the shortcomings of the study could be eliminated by an analysis of the medical data originating in the Cornell Automotive Crash Injury Research Project. These data have the advantage of presenting for the first time in a national sample, a representative cross section of the population involved in automotive crash injury. These data include all injuries to the subject(s) as reported by the initial attending physician within twenty-four hours after the accident. This includes the time of accident, time of treatment, and the height, weight, sex, age and seated position of the occupant. Data concerning accident configuration (speed of impact, area of impact, deformation of structure, etc.) are also available to assess all aspects of the problem. These are considered acceptably objective accident and injury reports. The majority of whiplash injuries are recorded in the literature by the consultants and specialists called in to care for these patients at a later date—a situation which may prove a shortcoming in reporting accurate details of an accident and the original time of onset and character of symptoms. It is our attempt to analyze the Automotive Crash Research data and to correlate the type of accident with the type and severity of cervical injury. By so doing we hope to bring into better focus the relative scope and type of problem encountered by the physician treating the victim of the automotive crash.

OBSERVATIONS

Among 12,764 persons involved in 5,710 rural highway automobile accidents in which injuries occurred, there were only 144 (1.1 per cent of all occupants) examples of whiplash injuries. In this study whiplash has been defined as any cervical injury, or complaint of cervical pain, sustained during an accident in which investigative evidence exists that the decelerative force was primarily one producing "whipping" of the patient's neck; any contact of the head against interior structures was considered of minor severity and did not contribute *per se* to the injury to the neck. This includes all types of forces, not necessarily impact to the rear of the vehicle alone. The 144 examples of whiplash injury represent 1.1 per cent of the total occupants exposed and 1.6 per cent of the total 9,063 injured in these 5,710 automobile accidents in which injuries occurred. It should be noted that 80 per cent of the injuries did not fall into the serious-to-fatal medical categories. (Fig. 1.)

Rear-end collisions comprise 3.6 per cent of the impact configurations of the 5,710 accidents in which injuries occurred. Rear-end accidents occurring less than one in twenty, therefore represent a small segment of the total accident experience.

In rear-end collisions 8.5 per cent of all occupants exposed sustained whiplash injury, 13.8 per cent of all occupants injured in rear-end collisions suffered some type of whiplash. This observation should be compared with the injury experience in other type collisions. In this group, 0.7 per cent of all occupants were reported to have sustained whiplash injuries and only 1 per cent of the injured occupants were reported to have sustained whiplash injuries. While there is a ratio of 12:1 increase in the risk of whiplash injury associated with rear-end collisions, it should be kept in mind that there are sixteen times as many people involved in other type collisions as in rear-end collisions. All these observations tend to bring immediately into proper perspective the relatively small group of people in whom a whiplash phenomenon occurs and in whom a serious injury is sustained as a result of this whiplash phenomenon.

The difference in frequency of whiplash injury between drivers and passengers in both rear-end collisions and other type collisions in all seated positions is reported in Tables 1

TABLE 1
FREQUENCY OF WHIPLASH IN REAR-END COLLISIONS

Seated Position	Incidence (%)
All drivers	7.7
All passengers	9.1
All injured drivers	12.7
All injured passengers	14.4

FIG. 1. Diagnosis: whiplash only.

and II. The differences observed are not statistically significant. If one compares the incidence of whiplash injuries in passengers in the front seat with those in the rear, one will find approximately the same frequency of whiplash injury in the drivers as in the passengers in the rear seat. However there is a relatively higher incidence of reported injury to the cervical spine in passengers in the right front seat (Table III). One hypothesis to explain this difference might be based on awareness of the driver of the impending accident and the higher seat and storage shelf in the rear, which restrain the head of the passenger in the rear seat from the whipping effect caused by a rear-end collision. The following observations are presented:

TABLE II
FREQUENCY OF WHIPLASH IN OTHER THAN REAR-END COLLISIONS

Seated Position	Incidence (%)
All drivers	0.6
All passengers	0.8
All injured drivers	0.8
All injured passengers	1.2

Only 1 per cent of all persons injured in accidents are reported by the initially observing physician to have sustained whiplash injury.

Passengers in the right front seat have sustained a moderately higher incidence of this type of injury, probably due to lack of head rest protection and lack of awareness of the impending crash.

The whiplash phenomenon is associated twelve times more frequently with rear-end collision than with other types of collision, yet rear-end collisions comprise only 3.6 per cent of accident experience.

It appears from the preceding data that whiplash injury comprises a very small segment of the population injured in automobile accidents and certainly in this small group not all patients require definitive medical attention.

MEDICAL DATA

In 5,710 accidents in which 12,764 occupants suffered injury, only 144 (1.1 per cent) persons in this large crash injury population were reported by the examining physicians to have sustained whiplash injury. To repeat, whiplash has been defined for the purposes of this presentation as any cervical injury or complaint of cervical pain sustained during an accident in which investigative evidence exists that the decelerative force was primarily one producing whipping of the patient's neck. Any contact of the head against interior structures was considered of minor severity and did not contribute *per se* to the injury to the neck.

Of the reported injuries, there were three distinct descriptive categories evident. The first group is comprised of severe injuries carefully detailed by the reporting physician (i.e., fracture of the body of the fifth cervical vertebra, etc.). The second group is comprised of less severe injuries and generally listed as "sprain" or "strain." A third group has no descriptive terminology concerning the cervical injuries other than whiplash or "cervical" pain and lacks a detailed report of anatomic description or clinical syndrome. This last fact is significant, since injuries in any of the other five areas of the body (head, thorax, extremities, etc.) have been delineated in great detail as to size or nature of lacerations or contusions.

TABLE III
FREQUENCY OF WHIPLASH INJURY IN DRIVERS VERSUS PASSENGERS IN THE RIGHT FRONT SEAT AND REAR SEAT

Seated Position	Rear-end Collision (%)	Other Type Collision (%)
All drivers	7.7	0.6
Right front seat	13.8	1.0
All rear seat	6.1	0.4
All injured drivers	12.7	0.8
All injured passengers in the right front seat	20.0	1.2
All injured passengers in the rear seat	9.6	0.8

TABLE IV
TYPES OF INJURY TO THE NECK (144 CASES)

Diagnosis	Incidence
Whiplash only	66 (46%)
Sprain and strain	51 (35%)
Fracture or dislocation	27 (19%)

Of the 144 whiplash injuries (Table IV), sixty-six (45 per cent) were reported by the examining physician as whiplash injury; fifty-one (35 per cent) were reported as a sprain or strain and twenty-seven (20 per cent) were classified with a specific anatomic diagnosis such as fracture, dislocation or injury to the spinal cord. It is significant that in a highly restricted group of injured people (i.e., 1 per cent of the population injured in crashes) only 20 per cent suffered an injury which required other than symptomatic care. Despite adequate examination, there was no clear-cut serious clinical entity in 80 per cent of these patients.

The severity of the sustained injuries to the neck has been recorded previously. (Table v.) The criteria employed in determining the severity of injury have been outlined in a previous publication [1]. Again it is significant that of this group of injured patients, only twenty-seven (20 per cent) suffered a severe-to-fatal injury, while the majority (117 [80 per cent]) sustained injuries not dangerous to life or requiring prolonged or involved medical care. These figures suggest that this extremely small group of seriously injured patients with whiplash injury has received more than its share of attention by a large segment of the medicolegal practitioners and authorities.

TABLE V
SEVERITY OF INJURY TO THE NECK

Diagnosis	Incidence
Minor to moderate	117 (80%)
Severe to fatal	27 (20%)
Total	144

Table VI has divided the three major classifications of whiplash into those not associated with injuries to other areas of the body and those associated with varying degrees of injuries to other body areas. Of these sixty-six whiplash injuries, thirty-four people (52 per cent) suffered no injury to another area of the body. Twenty-two (33 per cent) of this group suffered only an extremely minor injury associated with the reported injury to the neck. Seven (10 per cent) sustained a moderate injury to other body areas, and only three (5 per cent) had a combination of whiplash injury and a serious injury to another area of the body. Therefore, of the sixty-six patients in whom a rather loose diagnosis of whiplash was recorded, 85 per cent had no associated serious injury to another body area. (Table VI,A.)

Of the fifty-one patients reported to have sustained a sprain or strain, sixteen (31 per cent) had no injuries to areas other than the neck, and twenty-three (45 per cent) suffered minor associated injuries to other than the cervical region. In this group of fifty-one patients, one-fourth (eleven patients) sustained associated injury to another area of the body serious enough to require treatment. (Table VI,B.)

In the group of patients suffering a serious injury to the neck, such as fracture, dislocation or injury to the spinal cord (twenty-seven patients), fourteen (52 per cent) had a serious- to fatal injury to another body area. (Table VI,C.) Although study of this small group of injured occupants cannot lead to statistically significant figures in such a study as listed in Table VI, there is a trend evident. One must be impressed with the paucity of concomitant serious injury to another anatomical area in the patients who have been reported to have sustained a whiplash injury only.

A significant observation to be drawn from the examination of Table VI lies in the ratios which exist between serious or fatal associated injuries to other body areas and the distribution of the patients with reported injuries to the neck. Of the sixty-six persons in whom the diagnosis was whiplash injury, only three (5 per cent) had serious injury to other anatomical body areas. Of the fifty-one patients with a relatively precise diagnosis of sprain or strain, only one (2 per cent) had a serious or fatal injury to another body area, whereas of the twenty-seven patients in whom the diagnosis was specific (fracture, dislocation,

TABLE VI
INJURY TO THE NECK (WHIPLASH) ASSOCIATED WITH INJURIES TO OTHER AREAS OF THE BODY

Diagnosis	Total No. of Injuries	No Associated Injury in Other Body Areas	Associated Injuries		
			Minor	Moderate	Severe-Fatal
A. Whiplash	66	34 (52%)	22 (33%)	7 (11%)	3 (4%)
B. Sprain or strain	51	16 (31%)	23 (45%)	11 (22%)	1 (2%)
C. Fracture, dislocation, etc.	27	7* (26%)	3 (11%)	3 (11%)	14 (52%)

* Five of these seven cars had trooper reports only. Evidence of lack of proper medical reporting of fatal injuries plus lack of autopsy reports on these rural accidents causing injury poses a question as to validity of this figure.

TABLE VII
INJURY TO THE NECK (WHIPLASH) ASSOCIATED WITH INJURIES TO OTHER AREAS OF THE BODY (REAR-END COLLISION VERSUS OTHER TYPE COLLISION)

Diagnosis	Total No. of Injuries	No Associated Injuries	Associated Injuries		
			Minor	Moderate	Severe-Fatal
Whiplash					
Rear-end collision (3% of accidents)	31	25	6	..	..
Other type collision (97% of accidents)	35	9	16	7	3
Sprain or strain					
Rear-end collision	25	12	10	3	..
Other type collision	26	4	13	8	1
Fracture, dislocation, etc.					
Rear-end collision	7	2	1	1	3
Other type collision	20	5	2	2	11

FIG. 2. Diagnosis: serious injury to the neck.

etc.) fourteen (52 per cent) had serious or fatal injuries to other body areas. Furthermore, five of these twenty-seven people had no medical report and it is likely that this 52 per cent ratio of serious associated injuries would be even higher had these detailed medical reports been submitted on five such seriously injured patients.

This correlation of serious injury to the neck with serious injury to other areas of the body suggests that if the diagnosis is whiplash injury (unaccompanied by other serious injuries), the injury to the neck, *per se*, should not in most cases be the basis of the often extravagant litigation claims which now are rather common. A loose term such as whiplash should not be considered an acceptable diagnosis in patients unable to demonstrate any serious recognizable injury pattern to the examining physician.

A further breakdown of these whiplash injuries into those sustained in rear-end collisions and those sustained in other type collisions (Table VII) interestingly enough reveals a predominance of solitary whiplash injuries, i.e., those unassociated with injuries to other body areas in patients involved in rear-end collisions. Yet, in the other categories (i.e., fracture, dislocation, etc.) there is no such

predominance of solitary injury to the neck in patients involved in rear-end collisions. The availability of data collected by such an epidemiological or multidisciplined approach to crash injury problems, leads us to wonder if the popularity of the association in previous literature of injury to the neck with rear-end collisions has not increasingly led the examining physician to attach this diagnosis to a relatively minor or almost non-existent complaint or physical finding.

To further substantiate the minor severity of injury to patients reported to have sustained whiplash, evidence of physical damage to the vehicles was investigated. While there was occasional overlap in vehicular damage when compared to the cervical injury spectrum, it was noteworthy that the majority of patients with a diagnosis of whiplash occupied vehicles exhibiting minimal damage. (Fig. 1.) In contrast, the majority of patients suffering serious injury to the neck occupied cars which were severely damaged. (Fig. 2.)

COMMENTS

In the largest available recorded accident experience, the incidence of whiplash injury has proved to be extremely small. There is an apparent risk pattern associated with seated location of the occupant and a definite association of whiplash phenomenon associated with rear-end collisions.

In contradiction to the great attention given this syndrome in current medical and legal publications, the incidence of all cervical injury is small and the incidence of whiplash injury is, by definition, even smaller. In this series less than 1 per cent of persons injured experienced this whiplash phenomenon and had complaints or documented findings after the accident.

Of this group of 144 persons (less than 1 per cent of all injured occupants) only 20 per cent were definitely known to have suffered a dangerous or fatal injury while the remainder were known to suffer no serious injury to the neck. One therefore notes that an even smaller group of persons (approximately 0.3 per cent of all injured) rarely suffer any serious injury to the neck as a result of the whiplash phenomenon.

Lastly, it is interesting that of the patients in this series reported with no diagnosis other than whiplash injury, over two-thirds suffered no serious injury to any other body area. Yet, in the patients reported with a definite diagnosis, such as fracture, sprain or strain, well over half had a coexisting serious injury to another body area. One may surmise from these data that some patients situated in the car involved in a classic rear-end collision, while sustaining no serious injury, find the environmental term of whiplash a convenient one in subsequent litigation proceedings.

The term whiplash injury is believed to be a poor one for the following reasons. Whiplash means only that the head and neck are subjected to a series of motions during and after accident impact. The term in no way describes a clinical, anatomic or pathologic entity. Because of the increasing frequency of litigation so often seen in the accident configuration causing a whiplash action to the head and neck, the conscious or unconscious desire for gain could well be present in the patient, and in many cases is not removed by the examining physician or consulting lawyer.

It is believed that the term whiplash injury is a misnomer and deserves a serious reappraisal in usage. Too often clinical diagnoses are replaced by this catchall phrase which at best should describe only an accident phenomenon and not an injury syndrome or clinical entity.

SUMMARY

From 5,710 accidents in which injury occurred, 144 cases of cervical injury were recorded in which a whiplash phenomenon was experienced at the time of accident impact. Accident patterns and severity of injury are discussed.

CONCLUSION

On the basis of evidence available in this study, serious cervical injuries caused by exposure to the whiplash phenomenon may be sustained; the majority are accompanied by moderate to serious injuries in other body areas.

If an alleged cervical injury is not associated with injury to another body area and is not accompanied by clear-cut clinical findings or roentgenographic findings, on the basis of these data the injury must be considered minimal or nonexistent.

The term whiplash injury is not a diagnosis.

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Clinical and Roentgenological Aspects of "Occult" Fractures of the Smaller Elements of the Cervical Vertebrae

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MUCH progress has been made in the roentgenographic examination of the neck since anteroposterior and lateral views were the sole order of the day. Oblique views, the extension and flexion laterals of Davis [8] and the more recent extension and flexion obliques of Boylston [6] have all contributed to the better visualization of the smaller elements of the cervical vertebrae and the demonstration of lesions hitherto missed.

Nevertheless, some years ago it became apparent to me that all these views were of little help in the proper evaluation of many patients with relatively minor whiplash, hyperextension-hyperflexion injuries to the neck and other relatively minor traumatic and non-traumatic complaints. Therefore, I undertook to make an anatomico-radiologic study of the cervical spine and determine the visualization of the elements of the cervical vertebrae. As I reported previously [2,3], it was determined that certain additional views were highly desirable for proper evaluation of the cervical spine. First, a modified occipitosubmental view of the upper cervical vertebrae is particularly useful for adequate visualization *en face* of C1. This is similar to the view advocated by Jackson [9] in 1936. Second, an anteroposterior view angled 30 degrees caudad visualized adequately and symmetrically the lateral masses, articular facets and laminas of the lower cervical vertebrae. (Fig. 1.) I find it most valuable to take both these views stereoscopically, preferably with the ultrafine focal spot (0.3 mm.) x-ray tube and a short focal spot to object distance [1]. Third, I believe an anteroposterior view angled 20 degrees cephalad demonstrates best the joints of Luschka.

The visualization of these areas is especially important because in my opinion and experience these areas are the ones most frequently affected by relatively minor injuries [2,3]. I was able to produce fractures of the small elements of the cervical vertebrae in cadavers by oblique hyperextension and hyperflexion forces calculated to be equivalent to that sustained by patients in moderately severe whiplash injuries. I have demonstrated apparently identical lesions in my patients. In both patients and cadavers, the types of fractures found were, in order of frequency, interarticular isthmus fractures of the lower cervical vertebrae, unilateral fractures of C1 involving the transverse process and/or the superior facet, and fractures of the lower joints of Luschka. (Fig. 2.)

Rotary subluxations of C1 with respect to the occiput are sometimes also demonstrable on the basilar view. This diagnosis is quite difficult, especially in the presence of unequal muscle tension twisting the head. Stereoscopic films are essential. The most satisfactory criterion is the demonstration of an asymmetrical relationship of the superior facets of C1 with respect to the occipital condyles, i.e., riding more anteriorly on one side than the other. Figure 3 shows such a case before and after reduction of the subluxation.

In both cadavers and patients the majority of these lesions were not adequately demonstrated on the routine anteroposterior, lateral and oblique views.

It should be noted, however, that properly evaluated routine studies may be of great localizing value. Figure 4A shows apparent hypermobility of the upper cervical spine. In my experience this type of hypermobility is compensatory to fixation lower down, and the important information to be gained is the limitation of motion in the lower cervical spine particularly about C6. The anteroposterior

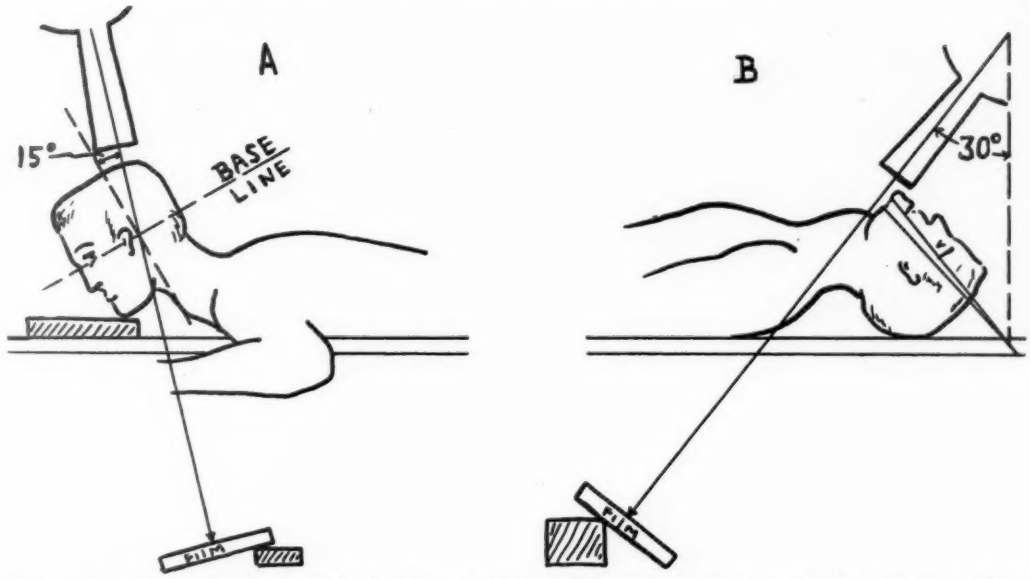


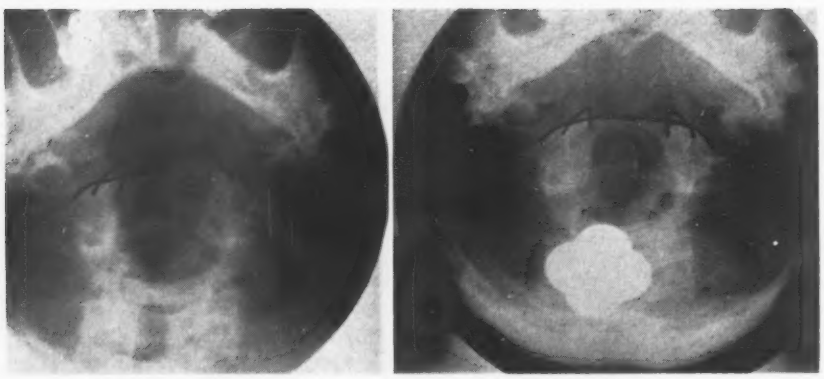
FIG. 1. A, positioning for the occipitosubmental view of C1 and the upper cervical vertebrae *en face*. (Compare with Figs. 2A and 3A and B.) B, positioning for the anteroposterior view angled 30 degrees caudad for visualization of the lateral masses, facets and laminas of the lower cervical vertebrae. (Compare with Figs. 2B, 4B and 5C.) Note: The diagrams for both these positions show the positioning for the fine focal spot short distance magnification technique I prefer. Standard distances and techniques may, of course, be employed. The angles shown are optimal in most cases but may have to be altered in individual instances.

2A 2B 2C

FIG. 2. Three cases of whiplash injury. A, occipitosubmental view of C1 in twenty-nine year old woman. The right transverse process of C1 has been broken off and rotated in two planes, anteriorly and inferiorly. Later films showed good reduction following traction, and good callus formation. The patient had a cord bladder persistent for months. The fracture was not visible on anteroposterior (open mouth), lateral or oblique views. B, anteroposterior view angled caudad of fifty-six year old man. This follow-up film shows displacement and fragmentation of the left superior facet of C6. The lesion was not noted on routine studies. C, anteroposterior view angled 20 degrees cephalad of twenty-four year old man. In this case the fracture through the sixth joint of Luschka was quite extensive and also visible on the lateral view. Late films showed development of hypertrophic changes and progressive thinning of the sixth cervical disc. A three-year clinical follow up showed atrophy of the biceps on the side of the lesion.

view, angled caudad (Fig. 4B), demonstrates that the patient's lesion is, indeed, at the level of C6. Similarly, extension and flexion oblique views may serve to point up the side and level of fixation or limitation of mobility.

The lateral view should also be examined for evidence of soft tissue changes, notably an increase of the retropharyngeal and retrolaryngeal spaces. These lesions are not uncommon soon after injury due to hemorrhage and/or edema. In my experience they disappear in a few days or weeks without residue.



3A 3B

FIG. 3. Occipitosubmental views of thirty-five year old woman. A, demonstrates the rotation of C1 with respect to the occiput, anteriorly on the right and posteriorly on the left. The occipital condyles and anterior border of C1 have been outlined to show the relative displacement on the two sides. The patient complained of vertigo and diplopia. There was no history of recent trauma. B, film taken very shortly after traction demonstrating reduction of the rotary subluxation. Symptoms were relieved at this time, although they recurred later.

4A 4B

FIG. 4. A, lateral view of thirty-five year old woman demonstrates hypermobility of the upper cervical vertebrae which is secondary to fixation of the lower cervical vertebrae. The notable finding here is the fixation of C5 and C6 in a position of extension even though the neck as a whole is in flexion. B, the lesion of the lower cervical spine; the left lateral mass of C6 has been completely displaced posteriorly and on this view is superimposed on the lateral masses of C4 and C5.

Clinically, these patients with fractures of the small elements present a rather variable picture [*12*]. The most reliable finding is persistent point tenderness over the lesion. In fractures of the lower cervical spine, persistent aching of the arm and shoulder is present in over half the cases. Bitemporal and supraorbital pain and headaches, often with visual disturbances, occurred only with upper cervical lesions or concussion and was persistent in about half the C1 lesions. This is the reference of pain to be expected from the C1 area, according to Campbell and Parsons [*7*]. Diplopia is seen in some patients with C1 lesions, particularly those with rotary subluxation. Other symptomatology was quite variable and non-specific.

Follow-up clinical studies showed considerable variability in persistence of symptoms and objective residue. The persistent clinical findings did not correlate well with the amount of residual bony deformity seen on x-ray examinations. Hypertrophic changes were slow to develop.

I have seen several patients with what I

5A 5B 5C 5D

FIG. 5. This fifty-three year old white woman complained of six weeks' inability to raise her right arm sufficiently to type. The patient was injured eight years previously with little disability at time of injury or subsequently to time of present complaint. A, lateral view is essentially negative. Note lack of hypertrophic spurring anteriorly. B, anteroposterior view angled 20 degrees cephalad shows hypertrophic changes in the joints of Luschka on the lower right but gives no information on the lateral masses. C, anteroposterior view angled 30 degrees caudad shows quite apparent fracture deformity of the right lateral mass of C6, extending into the superior facet. The fifth apophysial joint is narrowed. D, oblique view demonstrates extensive hypertrophic changes in the fourth, fifth and sixth right joints of Luschka, with encroachment on the corresponding intervertebral foramens, probably accounting for the patient's symptoms. Note also that the superior facet of C6 is quite anterior to the inferior facet, with corresponding alteration in the planes of the apophysial joints, but the fracture demonstrated on the anteroposterior view angled caudad is not visible. On the opposite oblique view the lower foramens are seen to be clear without changes in the joints of Luschka. I believe the hypertrophic changes and symptoms are secondary to the old fracture of C6.

believe to be late effects of lesions of the small elements. A case in point is patient D. P. (Fig. 5.) This woman was in an automobile accident in 1948, had a sore neck for some months and was asymptomatic until 1956, when she was forced to stop work as a typist because of inability to raise her right arm. X-ray examination disclosed what to me was a rather obvious healed fracture of the right articular isthmus of C6, with a quite characteristic anterior displacement of the superior facet of C6 with respect to the inferior one. The most interesting findings were on the oblique view, showing the abrupt change in the planes of the apophysial joints from the sixth to the seventh, and the extensive hypertrophic changes of the sixth, fifth and fourth right joints of Luschka with encroachment on the corresponding intervertebral foramens. I believed that these changes focused at and just above the level of the old fracture of C6 and were probably secondary to it. These hypertrophic changes in the posterolateral elements were in rather marked contrast to the lack of hypertrophic changes in the vertebral bodies anteriorly.

In many instances, however, evidence of old injury and extensive hypertrophic changes are present with no related symptomatology. In fact I have found such changes so frequently that my diagnosis of recent injury has been

affected quite markedly. In all but the most obvious cases, I insist on follow-up examinations and the demonstration of osseous change before making a definite diagnosis of recent injury.

Additional experimental and cadaver studies were made in an attempt to clarify the situation.

EXPERIMENTAL AND LABORATORY DATA

Normal Studies. A group of subjects were selected for normal controls. These people were asymptomatic and volunteered no traumatic history, yet quite early in the study it became apparent that a number of them had quite deformed vertebrae. Upon closer questioning, they could recall half-forgotten traumatic episodes of possible relevance.

These traumatic episodes were often not of great severity, but I demonstrated on cadavers that these fractures do not require great force. I believe that many people, with or without fracture, have had cervical injuries of similar magnitude.

Another approach was needed; the asymptomatic subjects, without obvious traumatic history, apparently did not constitute a normal control group.

Several thousand routine x-ray films of the chest were surveyed with attention to the cervical spine. On approximately one-third the lower two or more cervical vertebrae were seen reasonably well in approximately the same projection as on the anteroposterior 30 degree caudad-angled view. The bony detail in these films is frequently not good, and it is recognized that such a study is incomplete and biased in favor of the type of neck with a particular obliquity of the lower facets.

Nevertheless I believe such a study is valid for a mass study of the occurrence, at various ages, of gross abnormalities of the lower lateral masses. In this series I recorded as abnormal those with markedly irregular lateral masses and/or gross compressions or asymmetries. Minor asymmetries and hypertrophic changes alone were not considered abnormalities. There is no implication intended that the abnormal vertebrae are all old fractures, and I have no way of knowing what proportion are traumatic.

The results in some 1,100 cervical spines so visualized (Table 1) show that the incidence of abnormalities is quite high at all ages over one, and it increases with age. The incidence of 8.4 per cent under the age of twenty is especially surprising.

TABLE 1
SURVEY OF LOWER CERVICAL SPINE FROM X-RAY FILMS OF CHEST

Age Group (yr.)	No. of Cases	Abnormal	
		No.	Per cent
0–1	18	0	0
1–20	203	17	8.4
21–40	418	46	11.0
41–60	296	61	20.6
61 and over	139	57	41.0

I concluded that the abnormalities noted were acquired and not congenital, since the incidence increases with age. Moreover, in the main, they are not part of the aging process, as we usually think of it, because of the high incidence in the early age groups. (The sharp increase in incidence past the age of sixty may be largely due to the usual wear and tear of the aging process.)

Cadaver Studies. The necks of thirty-one cadavers were studied radiologically and anatomically, both macroscopically and microscopically, from two aspects: (1) for evidence of premortem fracture and (2) for localization and extent of hypertrophic changes, and any correlation thereof with evidence of old fracture. The cadavers were selected at random from those used for teaching and dissection in the Anatomy Laboratory.

Fracture data: Premortem county hospital records were available for about half the specimens. There was a history of pertinent trauma in one case; the patient had fallen out of bed, striking his head, four months prior to death. In no other case was trauma a significant part of the history, nor were symptoms referable to the cervical spine listed among the patients' major complaints.

The one patient who had fallen from bed had evidence of a healing fracture of the right interarticular isthmus of C6 laterally. The entire articular process was compressed laterally, and the superior facet was displaced anteriorly with respect to the inferior facet. On microscopic section there was evidence of fibro-osteoid tissue and cement lines, quite characteristic of healing fracture. (Fig. 6.) Micro x-ray films of this healing area were especially interesting because this was an area of regenerating bone.

Of the other thirty cadavers with no signifi-

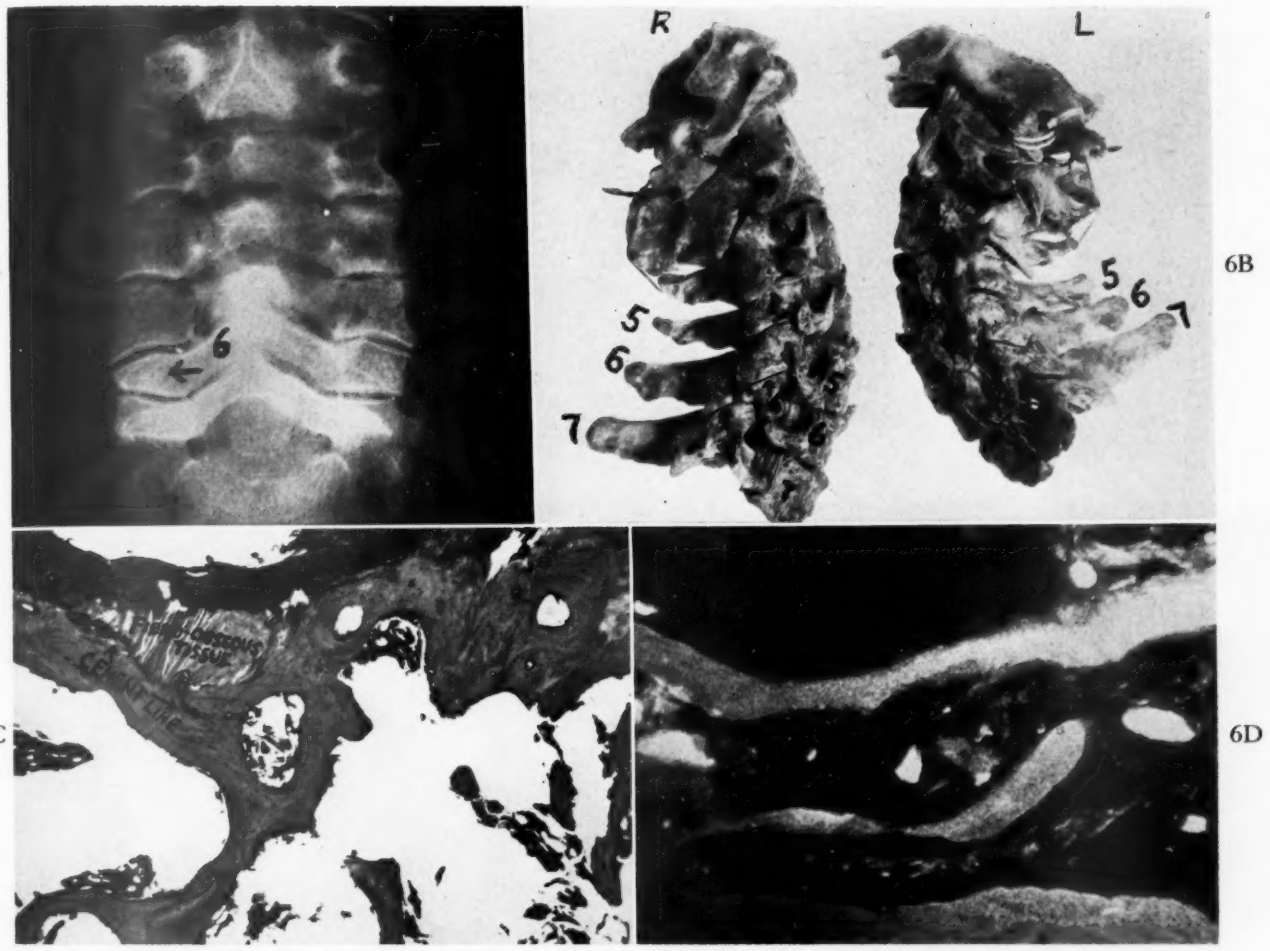


FIG. 6. Studies of cadaver 1. This subject fell out of bed four months before death, injuring his head and neck. A, anteroposterior view angled 30 degrees caudad shows lateral compression of right articular process of C6 together with alteration in the internal structure of the bone in the interarticular area. B, right and left lateral views of the gross specimen. Note the anterior displacement of the superior facet of C6 on the right as compared to the inferior facet. This was quite a characteristic shearing deformity found repeatedly in interarticular isthmus fractures in cadavers and patients. (Compare with Fig. 5D.) C, high power microscopic section through the compressed right interarticular isthmus of C6. Osteoid tissue and cement lines indicative of a healing fracture are demonstrated. D, microradiograph of bone from same area as microscopic section shows the irregularity of trabecular structure and variation of bone density indicative of the presence of new and old bone. This is the picture of regenerating bone.

cant traumatic history available, eight showed evidence of healed fractures involving the lateral mass of one of the lower articular processes from C4 inferiorly. Other areas were involved to a lesser degree.

The following factors were considered and correlated for criteria to establish the diagnosis of fracture: (1) The x-ray film of the gross specimen, demonstrating gross deformity of both contour and internal structure. Mere asymmetry and variation of height of a lateral mass was considered insufficient. (2) The gross anatomical deformity corresponding to the radiologic deformity. (3) Microscopic distortion of structure and trabecular pattern, with gross alteration in the lines of stress, corresponding to the macroscopic anatomical abnormalities and the structural change noted by x-ray examination. (4) Microradiographs of the same areas demonstrating variations in density and structure in the trabeculae indicating the presence of mixtures of new and old bones.

Amprino [4,5] demonstrated in 1952 that in microradiographs variations in the radiographic density of haversian systems is due principally to differences in the age of the bone—the youngest osteons being the least calcified. This work was confirmed by LaCroix [10] in 1953 by autoradiographic studies in animals, and reconfirmed later with histologic techniques by Cohen and LaCroix [11].

Figures 7 and 8 illustrate studies of two

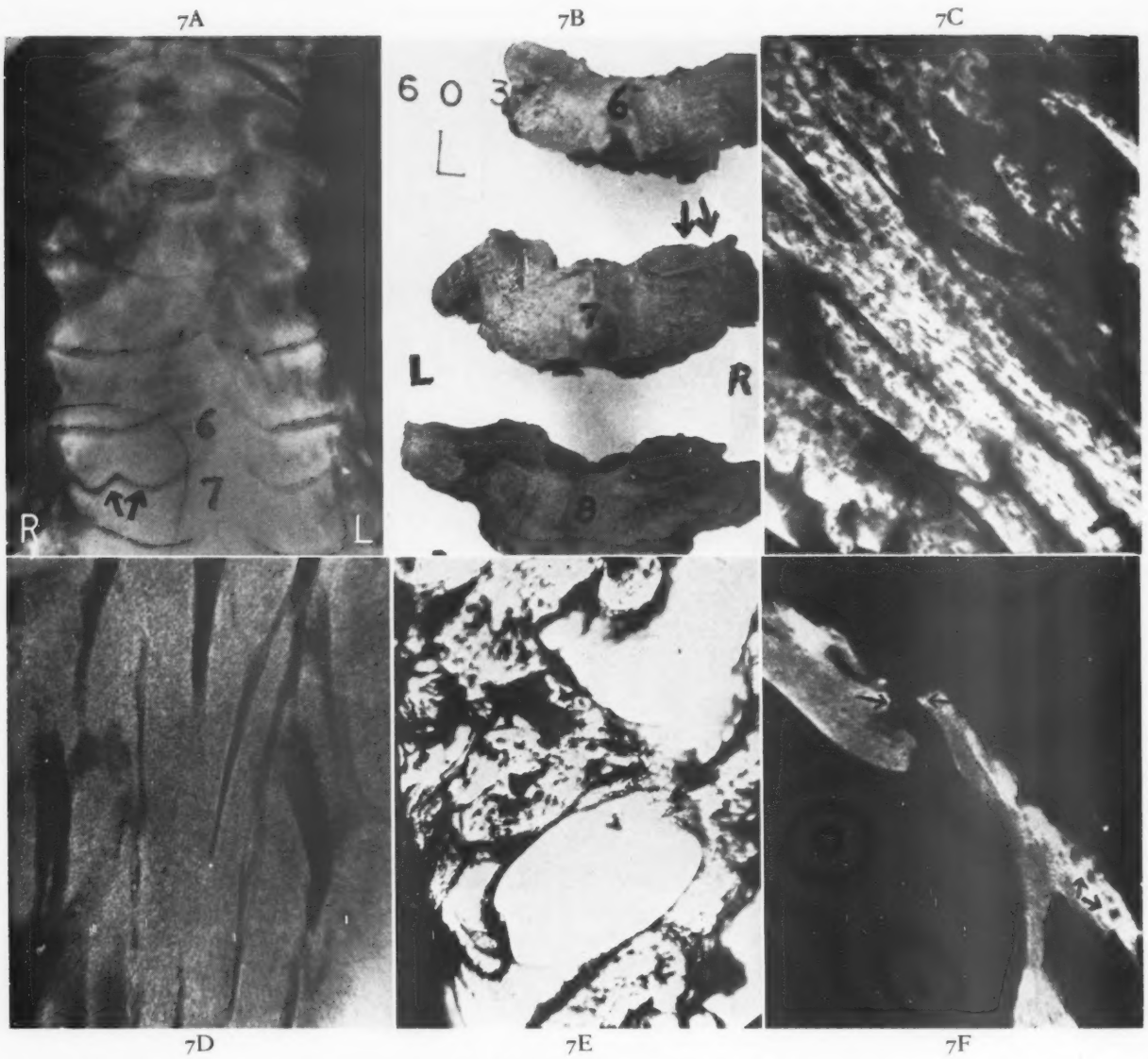
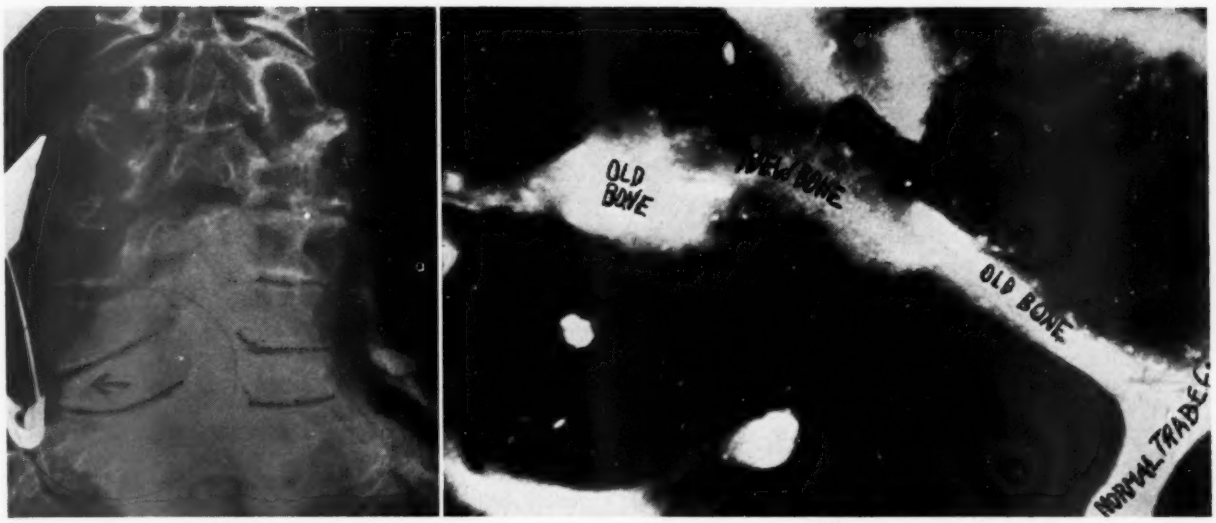


FIG. 7. Studies of cadaver 2. A, anteroposterior view angled 30 degrees caudad demonstrates marked sigma-shaped deformity of the superior joint surface of C7 on right. B, gross specimen, showing the actual deformity of the affected facet as compared with normal facets of vertebrae at levels above and below and on opposite side. The line through the facet on the opposite side is the area from which a section was removed and filled in with wax. C, microscopic view of this bony section from normal left superior facet of C7. Note regular bony trabecular pattern. D, microradiograph of same normal bony section. Note regular pattern of trabeculae and uniform calcification with sharp borders. E, microscopic view of bony section from abnormal right superior facet of C7 showing grossly irregular trabecular pattern with multiple cystic areas and fuzzy contour of bone. Abnormal sections from all cadavers were notably friable and cystic. F, microradiograph of same abnormal bony section. Note the trabeculae and irregular calcification and fuzzy contour. Upper arrows point to dark bridge of new bone joining two well calcified, fairly normal trabecular fragments. Lower arrows show small punched-out dark areas in bone. This I believe is the picture of new and old bone, normal and abnormal, representing a healed fracture.

additional cadavers, showing the correlation of the x-ray films and anatomical studies with the microradiographs. The marked variations in structure and density of the trabeculae on these microradiographs is in marked contrast with the regular structure and uniform density of the normal section. These abnormal sections have much the same characteristics seen in the microradiograph of an area of bone known to be a healing fracture. (Fig. 6.)

Osteoarthritic changes: Almost all of the specimens showed hypertrophic changes to some degree. The types of change were grouped as follows: (1) gross involvement of both the vertebral bodies and apophysial joints, the latter to a lesser degree; (2) gross involvement of the



8A 8B

FIG. 8. Studies of cadaver 3. A, anteroposterior view angled 30 degrees caudad shows marked lateral compression of C6, lateral mass indicated by arrow. The specimen also demonstrated the characteristic shearing and displacement anteriorly of the superior facet of the involved articular process. B, microradiograph of the affected articulation shows quite clearly fairly normal dense trabecular fragments joined by fuzzy, irregular dark bridges of new bone, the picture of a healed fracture.

vertebral bodies, particularly anteriorly, with little or no involvement of the apophysial joints; and (3) involvement of the apophysial joints and joints of Luschka with little or no hypertrophic change of the vertebral bodies anteriorly.

In this last group, in every instance, there was a malalignment of the facets, usually by reason of a deformity of one or more articular processes. Four of the cases with fracture deformities of the lower cervical vertebrae were included in this group. In every instance of deformity of the articular process, the hypertrophic changes were focused about the level of the lesion—for several levels on the same side at and above the lesion and to a lesser extent contralaterally. The changes were quite comparable to those of patient D. P. (Fig. 5.)

The other cases of fracture deformities of the lower cervical vertebrae were included in the first group and showed hypertrophic changes in the apophysial joints as well as elsewhere.

From these observations it is my opinion that: (1) Hypertrophic changes anteriorly of the bodies of the cervical vertebrae occur independently of hypertrophic changes in the apophysial joints and for different etiologic factors. (2) The anterior spurring is probably the result of static factors, notably the stresses and strains of weight bearing. (3) The hypertrophic changes in the apophysial joints are a response to a malalignment of facets and to an alteration in dynamic factors, i.e., changes in the planes of movement of the cervical spine. One of the noteworthy etiologic factors in this regard is fracture deformity of the articular process. (4) Since the cervical bodies, intervertebral discs, apophysial joints and joints of Luschka all are integral parts of the same suspension system, an alteration in one is eventually manifested by alteration in one or more of the others.

CONCLUSIONS

1. Clinical and experimental evidence indicates that fractures of the smaller elements of the cervical vertebrae are quite common as a result of relatively minor injuries, including among others the hyperextension-flexion traumas of so-called whiplash injuries.

2. The symptomatology from these fractures is quite variable in degree and duration, and these fractures may be quite asymptomatic when healed.

3. In my experience lack of symptomatology and lack of a freely volunteered traumatic history were insufficient criteria for determining a group of control subjects with normal cervical spines.

4. There is evidence to indicate that rather extensive osteoarthritis may be focused about these fracture deformities of the lower articular processes. Such changes are symptomatic in some cases, but in many cases are not.

Acknowledgment: Grateful acknowledgment is made to the Anatomy Department of the Medical School of the University of California at Berkeley for their gracious cooperation and use of their facilities; to Dr. C. W. Asling, Professor of Anatomy at the Medical School of the University of California, for his personal aid and his suggestion for the application of microradiography to this project; to the X-ray Department of Stanford University Hospital and the Alameda County Tuberculosis Association for the use of the x-ray films of the chest.

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DISCUSSION OF PAPERS BY DRS. HOLINGER AND JOHNSTON; MURPHY; BRAUNSTEIN AND MOORE; AND ABEL

R. Burns Lewis (Chicago, Ill.): About a year and a half or maybe two years ago I was talking to some radiologists from the West Coast who told me something about Dr. Abel's technique of examination of the cervical spine. It is a pleasure to hear more about his work firsthand.

Dr. Abel's first conclusion is a little startling to me. Although we do not have a large volume of traumatic work either at the hospital at which I am affiliated or at our office, we do see a goodly number of patients with so-called whiplash injuries. Frankly, the number of cases in which we have been able to demonstrate bony change has been quite minimal. Perhaps we have been missing these fractures which have been discussed. Time alone will tell. So far our routine includes taking anteroposterior and oblique views plus laterial flexion and extension studies. I am sure we will add the two views Dr. Abel has described—the occipitosubmental and the 30 degree caudal—to see if we can improve our results.

Lacking a .3 mm. focus tube, we and probably the majority of radiologists will have to be content with a 1 mm. focal spot and the magnification afforded by the distance between the part and the film in a Potter-Bucky tray. In these days of almost mass hysteria relative to radiation one must weigh very carefully the value of any procedure which multiplies the radiation by a factor of two to three or even more.

I believe all radiologists are in accord with the statement that extensive hypertrophic changes may occur around old fracture sites or sites of old injury.

I do not feel qualified to comment on Dr. Abel's other two conclusions, but I am intrigued by his inability to find controls with normal cervical spines by volunteered history and symptomatology. Perhaps one can add the cervical spine to the old adage that "all are queer but me and thee." Certainly, as Dr. Abel has stated, in all but the most obvious cases follow-up films with the demonstration of definite bony reparative change are a necessity before one can make the definite statement that there is evidence of a recent fracture.

Paul H. Harmon (San Francisco, Calif.): I believe the Association is fortunate indeed in having Dr. Abel summarize his researches on this particular phase of the effects of trauma to the cervical spine. Obviously, none of us can fully appreciate this work without several readings of the published manuscript. Lest many of those in the audience would gain the impression that the mere discovery of fractured lateral mass elements signifies a recent traumatic experience, allow me to quote a sentence from Dr. Abel's manuscript: "In all but the most obvious cases, we insist upon follow-up examinations and demonstration of osseous changes before diagnosing recent injury." Dr. Abel's scientific demonstration of reparative bone in cadavers by microradiographic methods has covered this point.

The practicing surgeon dealing with cervical and head injuries (the two are frequently seen together) is interested in whether gross cervical instability is present in the acute emergency case. Of course, the

complex radiographic investigation outlined by Dr. Abel will first have to be preceded by one or more scout films to cover this point. The small element fractures described by Dr. Abel are generated by obliquely directed cervical trauma. If we consider most automobile injuries, it follows that few have been produced by a perfectly symmetrically directed force. Theory dictates that the unilateral small element injuries are likely to be common, and that is my personal experience.

Most of us will be most interested in the bearing of the small element osseous injuries in the management of the patient who has sustained trauma to the head and neck. In the severely injured patient these particular injuries do not alter the usual method of treating injuries to the head, gross cervical instability fractures and major fractures elsewhere, but when one or several such smaller injuries are discovered in the absence of classic injuries to the head and neck, the management depends upon the symptoms offered by the patient. With very few exceptions, the thirty or forty patients with acute injuries of this type whom we have seen during the past two years have had more severe pain than is usual. This has prompted us to hospitalize most of them for seven to fourteen days of head halter traction with the cervical spine in slight to moderate flexion, as this position seems to be the most comfortable. This is followed by about sixty days of rigid cervical bracing. Ultrasound and/or hot moist packs (not both) with sedation are often used. Again I want to quote from Dr. Abel's manuscript: "persistent clinical findings did not correlate with the residual bony deformity seen on the x-ray films."

In the patients with chronic complaints who come for legal evaluation or treatment months after an alleged trauma, the finding of the small element injuries must be interpreted conservatively, merely described and a loophole left in interpretation as to the time injury occurred. Also, in our experience, hospitalization of these patients with chronic pain is useful both for treatment and evaluation. We seldom use rigid bracing for this latter group, depending of course upon the degree and distribution of the symptoms.

In our zeal for interpretation, based upon the injuries described by Dr. Abel, we must not forget the well known causes of headache, vertigo, visual disturbances and associated nausea, especially in elderly patients who think more about their injuries and have more time for litigation. I need not enumerate these common causes.

Finally, I would like to quote a third passage from Dr. Abel's paper: "Cervical bodies, intervertebral discs, apophysial joints and the joints of Luschka are all integral parts of the same suspension system; alteration in one is eventually manifest by alteration in one or more of the others."

Nelson J. Howard (San Francisco, Calif.): I want to arise in defense of Luschka who is no longer living. The joint is really a bursa until it becomes a part of the suspension apparatus by ossification of cartilage and ligamentous structures. We all know, if we are taught anatomy properly, that in embryonic life and in early infant life ligaments and muscles migrate and change their position. We also know, if we are familiar with the history of normal growth, that ligaments may ossify and cartilage may change into bone.

I want to congratulate Dr. Abel on his very excellent anatomical and radiological study. It is very difficult for most of us to accept something which is supposedly new. If we accept it slowly and a newer concept comes along, we again release or change our old concepts slowly.

Perhaps that is common sense to most of us but when the new concepts involve either financial responsibility or legal procedures, many of us defend the old far longer than we should or accept the new too eagerly. What we want is the truth; the truth never hurts much or too long. Just as in most so-called whiplash injuries, the patient does not have severe disabling pain except for work, and his pain never lasts long after a settlement is made.

We have also been given a new cause for arthritis. I was very grateful to have this problem of arthritis so easily explained.

What we really should do is to learn what and who is right in this whole problem, and it should be done without polemics and without prejudice. It may not be out of order to suggest that this Society appoint a committee of a radiologist, an anatomist and a surgeon to correlate the different viewpoints and to act in a sense as friends of the court in legal procedures throughout America.

James C. Drye (Louisville, Ky.): At a recent meeting in Detroit on highway safety, sponsored by M.E.N.D., an orthopedic surgeon from Texas convincingly presented the concept that whiplash injuries were not extension injuries but compression injuries. I would like to explain his theory.

The head, weighing about 15 pounds, in the usual driving position is thrust well forward. The trunk or back is in contact with the back of the seat. When the vehicle is struck from the rear, force is transmitted to the driver's back, driving it straight forward. The head tends to stay in its original position due to inertia. However, it must be driven up about 2 or 3 cm. to make room, as the head normally swings on the trunk in an arc. This causes a compression of the cervical spine. I submit this idea, which is not mine, for your consideration.

I would now like to report an unusual case of tracheal injury in a patient who was admitted recently to the Louisville General Hospital.

This young man was apparently struck by the rim of the steering wheel which completely severed

the trachea, without an open wound, at about the junction of the second and third rings. He was admitted directly to the operating room with severe cyanosis. The anesthetist tried to give positive pressure oxygen but it did not work very well. He could not get an airway established. We performed an immediate tracheostomy and found that the trachea was completely severed and the ends retracted for a distance of 3 or 4 cm. A low tracheostomy was performed and the ends of the severed trachea were approximated with interrupted silk sutures. The patient recovered without difficulty.

EDWARD SCHLESINGER (New York, N. Y.): There is very little left to be said after both papers on whiplash injury and Dr. Howard's magnificent summing up of the problem.

Last year I was one of the "gladiators" in Dr. Wade's symposium at the meeting of the American College of Surgeons and I tried to point out, using x-ray films taken after various forms of cervical trauma, that there are generally sequential changes in bone after injury. I think we have to define this problem, whiplash, as a syndrome in people who have no overt neurological changes and in whom there are no early or sequential bony changes in the cervical spine. Let us be sane, we are all talking about the same thing. Most of what Dr. Abel demonstrated so well we would agree upon as evidence of real injuries. There is no problem there and really nothing to discuss.

What presents a terrible moral problem in medicine is the whiplash injury with no such obvious evidence of pathology but with protracted disability. We have a subject here which lies heavy upon medical and legal conscience, I believe, and it is an entity which has almost replaced the postconcussion state as a medicolegal litigation problem.

We clinicians like to diagnose things which we can see, feel, hear, smell and look at on the x-ray film, and this syndrome is none of them. I think the major reason it is so popular lies in the impact of its name—whiplash—which in itself can convey such a vivid image of trauma. The legal profession and certain segments of the medical profession have given it such a "Madison Avenue" approach that the term is on every tongue after any presumed cervical injury. On the other hand, we have to keep the door open to the fact that there are things we do not understand. Dr. Howard properly hinted at this. Maybe there will arise among us someone who will teach us that there are, for example, injuries to the vertebral artery in these cases which we have not recognized and which cause some of the seemingly bizarre symptoms. I prefer to believe that is not so but we have to keep our eyes open and avoid emotional thinking. It is our serious medical responsibility to either prove that the syndrome is a pathological entity or lay its ghost forever. It presently is a great problem on our medical conscience. I would subscribe heartily to the kind of work that has been described by Drs. Braunstein and Moore, and Dr. Abel. I am in accord also with Dr. Howard's suggestion that we ought to put this matter on a firm basis by group study. This is certainly the sort of society which should bear such a responsibility.

NICHOLAS JAMES GIANNESTRAS (Cincinnati, Ohio): This is a subject which has been of great interest to me.

To begin with, I should like to ask this Society to consider seriously the establishment of a committee such as Dr. Howard suggested. This same group was responsible for performing some very fine work regarding the administration of gas gangrene antitoxin to which everyone was subjected prior to the tenets laid out by this Society.

The term whiplash injury, as Dr. Schlesinger brought out, suggests that the head is snapped with a terrific force such as at the end of a whip, and the average layman on a jury interprets such an injury that way. In and around Cincinnati we have tried to educate physicians as much as possible by terming this a flexion-extension injury to the cervical spine. To the average layman it does not indicate as much damage. The attorney does not like to hear it but certainly the settlements, from the standpoint of litigation, are materially smaller when a diagnosis is made of flexion-extension injury to the cervical spine. This is a more specific diagnosis than the term that unfortunately has been coined by the medical profession and accepted by everyone (and particularly by the legal profession) as standard diagnosis.

I think the work that Dr. Abel has done will be remembered, and I am certain that he will recieve innumerable requests from this Society for reprints of his paper. He mentioned something about diplopia as a frequent symptom associated with an injury to the first cervical vertebrae or to that immediate vicinity. As many of us remember, Dr. Mayfield described the cause for this diplopia some time ago. He said that with a severe injury to the cervical spine there frequently occurs an injury to the second cervical nerve root, and this in turn can be one of the causes for the diplopia associated with the flexion extension injury to the cervical spine.

PRESTON A. WADE (New York, N. Y.): We do not seem to agree on what we mean by the term whiplash injury. I believe that it is most improtant that we do not dignify this term by including in it organic lesions such as fracture or dislocation.

I think Dr. Abel's paper was excellent and will help to throw light on this problem.

We do not deny that injuries to the neck may occur when the neck is suddenly and forcibly extended. However, if an injury is sustained it should be given the term it deserves—fracture, dislocation or sprain. Whiplash injury is not a diagnosis but many people use the term loosely to describe subjective symptoms resulting from sudden extension of the cervical spine. As Dr. Schlesinger has said,

whiplash injury has almost displaced the postconcussion syndrome from the courts. Postconcussion syndrome was preceded by the once popular "railway spine," which fortunately is now rarely heard. I fear that whiplash injury is now becoming a popular legal term to imply injury when no organic injury really occurs.

J. W. BLUNT, JR. (Cleveland, Ohio): I want to ask a question about traumatic diplopia. We have had a number of such cases and they frequently occur in patients with multiple injuries. It is difficult to get an ophthalmologist at 2:00 A.M. to see these patients when the orbital fracture is fresh. By 10:00 A.M., when he does see the patient, there is too much swelling to evaluate the fracture. Is there a particular x-ray view that could be ordered by the surgeon before the patient is placed in balanced suspension, etc., that would help the ophthalmologist when he arrives?

MOORE MOORE, JR. (Memphis, Tenn.): As an orthopedic surgeon who has been educated by friends in the fields of ophthalmology and ear, nose and throat diseases, I would like to ask Dr. Murphy if he would comment on the use of an inflatable balloon in early fractures involving the orbital floor. It has been described by Dr. Harbert Anthony who has had considerable success with it. We have also been taught to look for these orbital rim and floor fractures in the first two or three hours after the patient is admitted. In this way, as you are examining for other things you can usually palpate such fractures very readily; this cannot be done later on when fixed swelling develops.

I would like to ask Dr. Murphy if he has had any experience in using bone graft for the graft described in the floor of the orbit.

JACOB KULOWSKI (Saint Joseph, Mo.): I am both pleased and honored to discuss this objective view of a perplexing, controversial and overlapping field of medical, engineering and legal endeavor. Dr. Abel has wisely chosen to limit his presentation to such clinical and radiological factors which have lent themselves to his personal experimentation and clinical observation. The facts, as he has presented them, speak for themselves, eloquently enough to satisfy anybody who will take the trouble to read this paper carefully after it has been published. I wish only to highlight some of these in the light of my own clinical experience and knowledge of the related literature on the subject.

First, Dr. Abel's special radiologic techniques have opened new vistas in the visualization of what he modestly calls minor to moderately severe whiplash injuries to the smaller cervical elements. Broadly speaking, he has divided the clinical manifestations into two major categories, arising from injury to the upper and lower cervical segments. The former produces head and visual disturbances; the latter is of a more local nature, with references in pain to the upper extremity. Such an organic interpretation is becoming more widely accepted by the medical and related disciplines.

In my own clinical experience with so-called whiplash injuries, the incidence of the more occult manifestations of cervical arthritis (apophysial and Luschka) is becoming increasingly evident. This also reintroduces the diagnostic challenge of the preimpact and/or postimpact significance of these arthritic findings.

I am inclinded to agree with Dr. Abel that these arthritic pitfalls, medicolegally speaking, are attributable in many cases to the post-traumatic effects of whiplashing, to the extent that fractures and subluxations have been produced in the contiguous anatomical cervical elements. One can hardly arrive at any other conclusion in the face of Dr. Abel's experimental and anatomical evidence in this regard. This is especially true with respect to the younger age groups who become involved in such injury-producing accidents more frequently than older people. The question of selective reasoning becomes more acute in the older age groups who tend to show more and more arthritic evidences; many forget the accident events which may have precipitated or initiated these changes in the first place.

The literature on this subject is growing rapidly, much of it being of a subjective nature, i.e., distorted by personal bias based largely on diagnostic frustrations occasioned by certain bizarre and persistent patient claims, especially by those who are involved in damage suits. I am grateful to Dr. Abel for having developed a precise radiological method for the detection of traumatic changes in the cervical spine which are otherwise missed by routine radiological techniques. The interpretation of these changes has become a matter of routine to the inventor of this technique. It only remains that its use be widespread for the achievement of greater refinements of these changes in a diagnostic sense.

ARTHUR L. MURPHY (closing): As a victim of a whiplash injury some years ago, I would like to assure any of you who do not know otherwise that it is a very descriptive term from the victim's point of view. However, it is not scientific. I like the term flexion-extension, but I would prefer it reversed to extension-flexion.

The small force required for an injury of that type is sometimes rather amazing. I was sitting in a heavy car when it was struck by a truck from behind. The car did not move more than 12 inches. There was no mark on it anywhere but I very nearly lost consciousness from the force of the blow. The effect it could have on a person looking toward litigation could well be tremendous, even though the injury itself is very slight.

I think Dr. Moore answered Dr. Blunt's question very nicely on how to discover these cases of diplopia early. The problem applies, I think, to all types of endeavor. As we advance we specialize, and

as we specialize we improve in certain directions. However, we do lose something in the over-all approach, and that is certainly true in surgery.

In our hospital nearly all patients involved in accidents who have concussions go first to neurosurgery. That is where they should go, but it is a separate unit and even though the neurosurgical team is very careful and very thorough I think sometimes the patient does not get the same general assessment he would in the general surgical ward.

As Dr. Moore has pointed out, if the specialty groups who are meeting these cases first just remember about diplopia—that it must be looked for early and that early correction is simple—then the major problems I have shown will not arise in later months.

I have had no experience with the intra-antral balloon to hold the fractures reduced that Dr. Moore mentioned. It sounds very practical.

In answer to the question about bone bank grafts, we have not used any. I am not too fond of them in any position, and I would be afraid of them in the orbit.

MARTIN S. ABEL (closing): In regard to the amount of radiation from so-called magnification technique, I would like to state first that this is not primarily a magnification technique. It is a short focal spot object technique and may be used with film in a Buckey tray. In my experience and experiments with wire screens and other inanimate objects, better detail was obtained in this fashion.

As far as the amount of radiation is concerned, with the use of 3 mm. of aluminum filter and sensitive film, and also because you do not use a Buckey tray when a film is below the table, the amount of radiation with one of these films is quite comparable to that with the routine technique. Furthermore, the amount of tissue radiated is frequently smaller because it is our practice to cone down very sharply.

Regarding Dr. Schlesinger's remarks on bony changes, I would just like to emphasize what I thought I said repeatedly in this paper and others: the x-ray frequently gives a very false sense of security. In some cadavers I have found fractures after dissection which I could not see on routine films of the cervical spine or special films in multiple projections. There was even one case in which I had a ½ inch saw mark that was not visible in any of the x-ray films except by happenstance.

The point of the matter is that a roentgenogram is merely a shadow; you can always make two shadows overlap so it looks like one shadow, but you cannot make one shadow separate into two. That is the fundamental thing about showing a fracture on x-ray film.

In response to Dr. Howard, I do not know whether the so-called joint of Luschka is an anatomic joint. I went through a number of anatomy books on the subject. There is one from Edinburgh that says very definitely it is a joint functionally. I believe it is a joint. However, let that be as it may.

The medicolegal aspects of this situation are very important and cannot be separated from the work, unfortunately. I was in Virginia recently and spoke at great length with Dr. Charles Frankel at the University of Virginia. They have been using this technique there for the last year or so. As a matter of fact, they have had considerable experience with it. Dr. Frankel, as some of you may know, is a member of the University orthopedic staff and is also an attorney. As far as excessive settlements are concerned, his experience and ours in San Francisco are somewhat similar. The point is not so much that someone demonstrates a small fracture on an x-ray film, because frequently in court, as Dr. Frankel has stated, it is not of great importance. Rather it is the great contrast between the demonstration of a small fracture and the opinion of the opposing medical witnesses that such fractures do not occur and that the patient is not hurt. This is all medicolegal hocus pocus. The jury thereupon sees a small fracture demonstrated. They must conclude therefrom that this is a strange and wonderful thing, and they accordingly give a disproportionately large settlement.

Personally, I do not think these fractures are any more important than rib fractures in many instances, as far as symptoms are concerned. The evidence I now have and the evidence I have seen indicate that these fractures are extremely common. If other evidence arises I will change my opinion, but as of now they are extremely common. If the jury understands that perhaps 25 per cent of the general population, including one or two of the witnesses, have had a similar fracture of the neck that they never knew about, they are not going to award an excessive settlement on the basis of fracture alone. This is equitable and, I think, the way it should be. I am not too experienced in symptomatology but obviously the jury's verdict should be largely based on this aspect of the case.

I believe that the diplopia in the patients we have seen has also been accompanied in most instances by a certain amount of rotation of C1 off the occipital condyles. This is explained in the work of Campbell and Parsons in the *Journal of Nervous and Mental Disease.** They point out that the flat muscles at the base of the skull are first, analogues of the muscles of the eye and, second, organs of balance. For example, if you cut out the middle ear mechanism of a cat, it will still fall on its feet, but if you cut the flat muscles at the base of the skull, it will fall on its head frequently.

These are important muscles. When there is injury and resultant imbalance in these muscles, the diplopia may be explained on this basis. It certainly explains a certain amount of vertigo which some of the patients also have.

* Volume 99, page 544, 1944.